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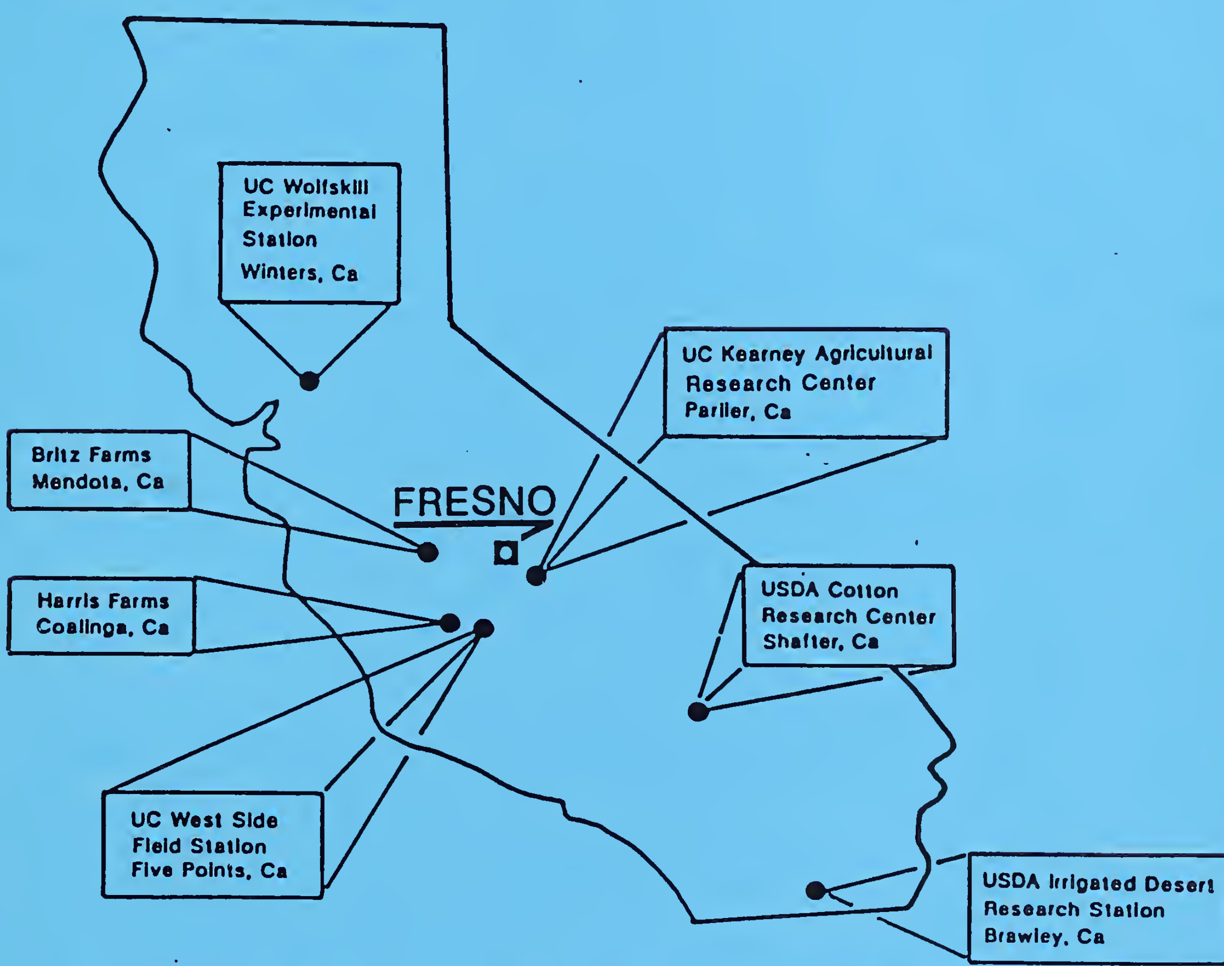

WATER MANAGEMENT RESEARCH LABORATORY

PROGRESS REPORT 1991

RESEARCH PROGRESS REPORT

1991

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INTRODUCTION

The Water Management Research Laboratory Research Progress Report is intended to inform upper level management within the Agricultural Research Service, other ARS research locations involved in natural resources research, and our many collaborators and cooperators about progress made on our research projects in 1991 and plans for 1992. It is our intent to keep the individual reports short but informative, focusing on objectives, approaches, summarized results and future plans for the projects. We want to emphasize that the product of our research is to develop improved irrigation, to contribute to water conservation and water quality, and sustainability of irrigated agriculture.

The overall mission of the Water Management Laboratory is to conduct research and to develop advanced water management practices, methods, equipment, and systems to utilize soil, water, nutrients, and energy resources efficiently and to improve sustainability and crop productivity in irrigated agriculture under water-limited conditions.

The Laboratory, in cooperation with personnel at the U.S. Salinity Lab in Riverside, CA, the U.S. Cotton Research Station at Shafter, CA, and the University of California, Riverside and Davis, CA, is continuously developing new CRIS research projects and is addressing specifically the issues of the impact of limited water supplies and drainage on water quality, water use efficiency, sustainability and productivity of western irrigated agriculture. Cooperative projects are funded by the California Department of Water Resources (DWR) and the State Water Resource Control Board, the Imperial Irrigation District (IID), the Metropolitan Water District (MWD) of Southern California and the Imperial Valley Conservation Research Center committee (IVCRCC).

We invite you to use this progress report and to forward your questions and comments to us at your convenience; they will be appreciated. We thank you for your support and interest.

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Research Leader

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WATER QUALITY MANAGEMENT WESTSIDE OF SAN JOAQUIN VALLEY-- BRITZ PROJECT I. PROJECT LAYOUT

J.E. Ayars, C.J. Phene, H.I. Nightingale, R.A. Schoneman, B. Meso and F. Dale

OBJECTIVES: As part of the Presidential Initiative on groundwater quality, the Water Management Research Laboratory developed a research project in cooperation with Britz Farms and the U.S. Salinity Laboratory to evaluate the impact of irrigation water management on shallow groundwater quality. The objectives of the project are:

(1) Demonstrate the effectiveness of irrigation systems and practices having the potential to significantly reduce the volume of deep percolation or water flow from tile drainage.

(2) Determine relationships between irrigation systems operation and chemical quality (total salinity, and concentration of potentially toxic elements) of the deep percolation water and shallow groundwater.

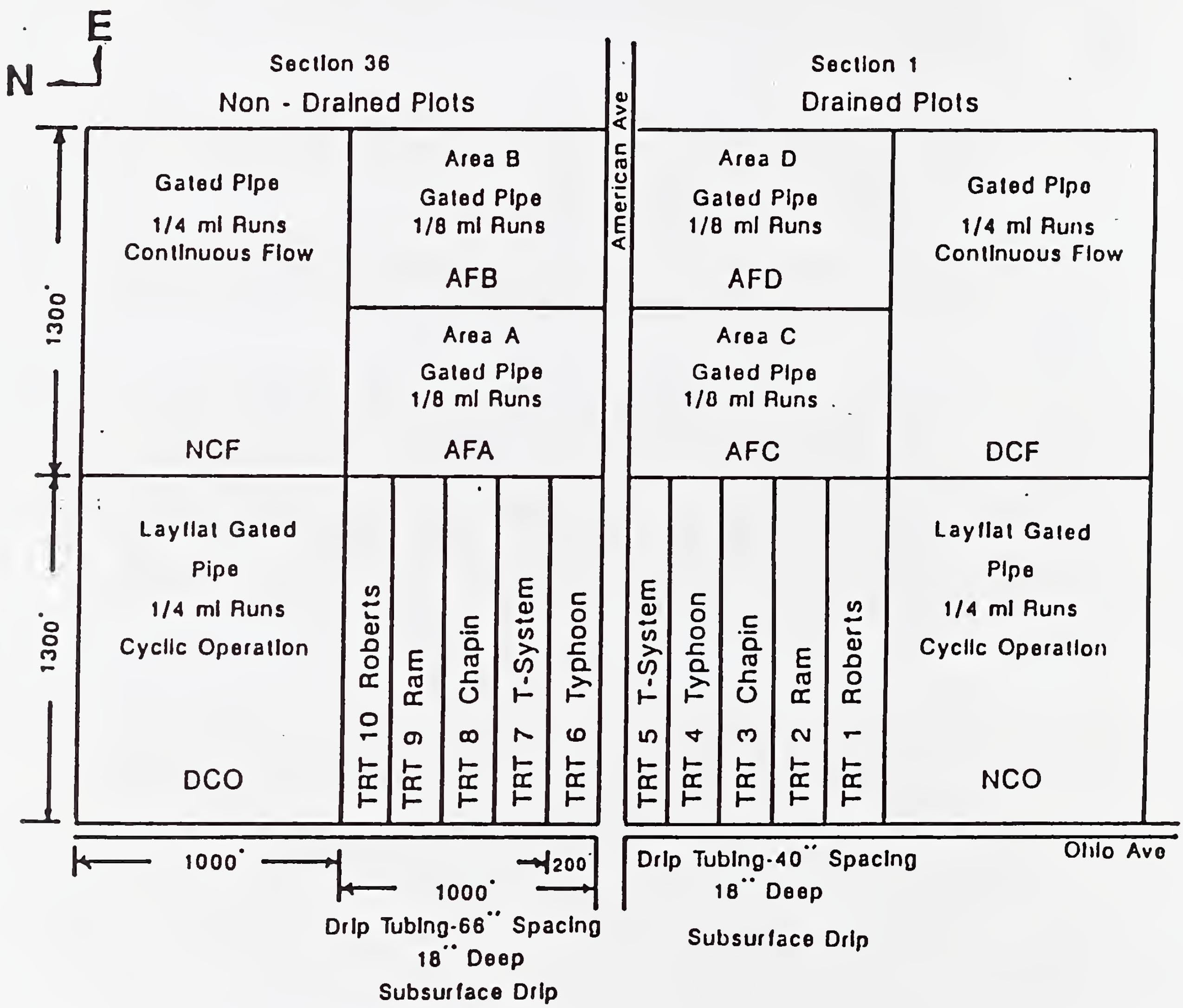
(3) Determine the relationship between the operational parameters of furrow irrigation and the volume and chemical quality of water from surface runoff.

PROCEDURES: After consultation with Mr. George Brazil, a site was selected on one of the Britz ranches south of Mendota, Ca. This site is in the San Joaquin Valley drainage problem area and has a shallow saline groundwater table. Two adjacent quarter sections were selected for use in the project because one field contained tile drains and the second did not. This set up provided a unique opportunity to develop groundwater management methods for both drained and undrained fields in a situation where similar management was possible. The study fields are the SW quarter of S36 T14S R14E and the NW quarter of S1 T15S R14E.

The systems selected for testing were subsurface drip irrigation (SDI), improved furrow irrigation using a prototype layflat irrigation tubing and modifications of the existing furrow irrigation practices using gated aluminum pipe. In addition to the subsurface drip plots, the following furrow irrigation systems were included: gated aluminum pipe on plots with 1/4 mile runs; gated aluminum pipe on 1/8 mile runs; and automated gated layflat pipe on 1/4 mile runs. The layflat pipe was developed by Allan Humphreys at the Soil and Water Management Research Unit in Kimberly, Idaho. The operation of the layflat was to be in a surge irrigation mode. Each of the plot areas was approximately 30 acres in size. The experimental layout is given in Figure 1.

<u>RESULTS</u>: The SDI installation was completed in the Spring of 1991 and the first season of operation was used to test the systems and make the necessary modifications in the design and operation. The fertilizer injector for the phosphoric acid was changed from a hydraulic operated system to a metered pump. The 20 hp pump for the system was found to be undersized and was changed during the winter. The layflat pipe was used for the first irrigations on both the cotton and tomatoes. However, due to the lack of pressure control available from the Westlands system it was not feasible to continue to use this system.

<u>FUTURE PLANS</u>: Commercial surge valves were purchased for use with the gated aluminum pipe. Cotton will be grown on both fields during the 1992 season. A paper will be prepared for presentation at the summer ASAE meetings.



WATER QUALITY MANAGEMENT WESTSIDE OF SAN JOAQUIN VALLEY-- BRITZ PROJECT II. COTTON DEVELOPMENT

J.E. Ayars, C.J. Phene, H.I. Nightingale, R.A. Schoneman, B. Meso and F. Dale

OBJECTIVES: Characterize the development of cotton grown using subsurface drip irrigation in the presence of a shallow saline groundwater.

PROCEDURES: Approximately, a quarter of the field was lost to production due to a high water table which resulted from excess irrigation outside of the field boundary. Plant development was monitored every two weeks throughout the growing season by measuring height, number of nodes and boll development. Cotton is a salt tolerant plant which is capable of extracting significant quantities of water from shallow saline groundwater. One technique used to insure that the maximum amount is withdrawn from the groundwater is to schedule irrigations using plant-based measurement such as leaf water potential (LWP). This method was tested during the 1991 growing season.

RESULTS: The final plants' heights and number of bolls prior to harvest are given Table 1. The data show that there is very little difference in plant height and boll numbers between the furrow and drip treatments.

The LWP data are given in Figure 1 for drip treatments 1, 2 and 5 and for the furrow irrigation treatments DCO and AFC. The data show that the crop was well irrigated throughout the season. A LWP value of -18 bars is generally used to initiate furrow irrigations later in the season after flowering has begun and this value wasn't reached in any of the treatments until very late in the season. A threshold of -14 bars is used to initiate irrigation early in the season. Irrigation was cutback to 0.08in. per day in the SDI treatments on August 14, 1991 (DOY 226) and ended completely on August 30, 1991. The last furrow irrigation of cotton occurred on August 14, 1991.

FUTURE PLANS: The research will be continued in 1992 with cotton being grown on both fields. The LWP measurements will be used again. Plant mapping as developed by extension specialists of the UC system will be used to evaluate the cotton development and aid in the management decisions. These data will also be used in a shallow groundwater management experiment.

Table 1. Summary of average cotton plant height and boll numbers at September 16, 1991 plant sampling at Britz research site.

Treatment	Height (in)	Small Boll	Large Boll	Open Boll
Trt 1	44	1	9.8	2.3
Trt 2	48	1.3	10.7	2.0
Trt 3	46	0.8	10.0	3.0
Trt 4	43	0.8	8.7	3.3
Trt 5	50	1.6	9.3	2.7
AFC	44	1.8	14	1.7
DCO(1)	42	1.5	11.0	1.3
DCO(2)	33	0.4	7.3	4.0

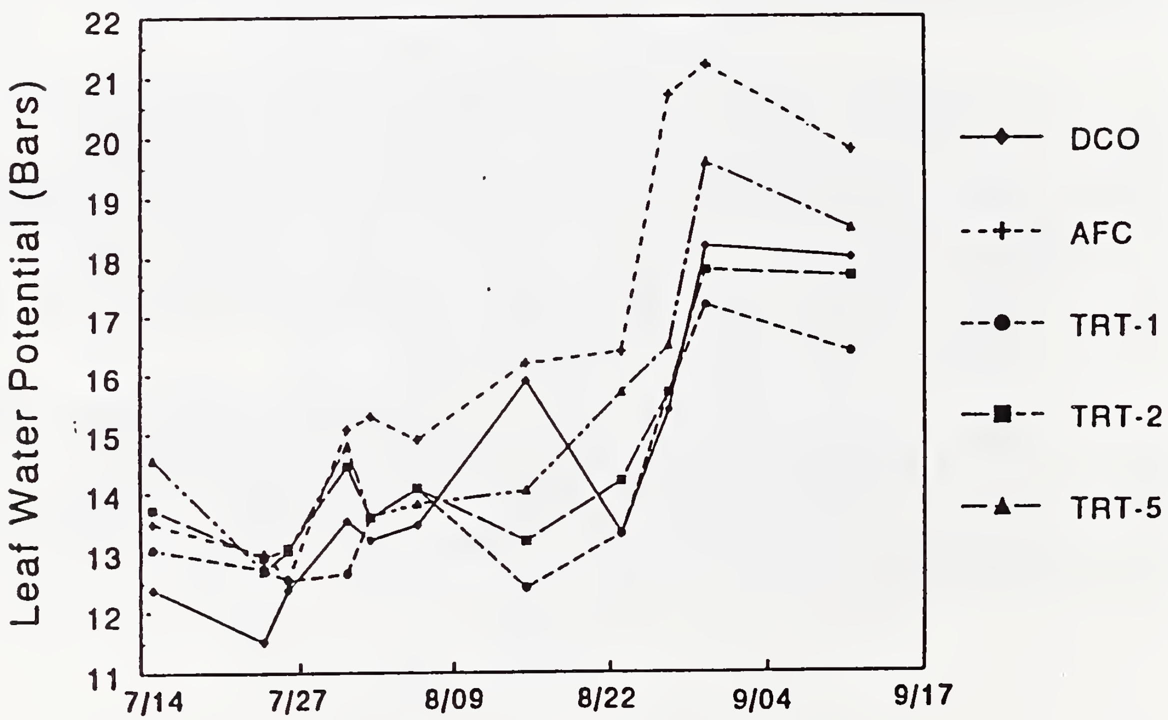


Figure 1. Leaf water potential data for subsurface drip treatments 1, 2, and 5 and furrow irrigated treatments DCO and AFC.

WATER QUALITY MANAGEMENT WESTSIDE OF SAN JOAQUIN VALLEY--BRITZ PROJECT III. COTTON YIELD

J.E. Ayars, C.J. Phene, H.I. Nightingale, R.A. Schoneman, B. Meso and F. Dale

OBJECTIVES: Compare the cottons yield in the SDI treatments and the furrow irrigation treatments.

PROCEDURES: Areas were machine harvested in each plot until a module was filled. Between 1 and 2 acres were harvested into each module. The module was marked and tracked through the ginning process. The harvested area was then measured and used to calculate the yields. The gin turnout was calculated using the lint and seed cotton yields.

RESULTS: The yields are summarized in Table 1. The yields were comparable across all treatments both the drip (TRT 1-5) and the furrow (DCF, DCO1, AFC).

Table 1. Summary of seed cotton and lint yields for the 1991 Britz project.

Treatment	Lint (lbs/acre)	Seed Cotton (lbs/acre)	Gin Turnout (%)
DCF	1308	3830	34.2
DCO1	1329	4058	32.7
TRT1	1324	3803	34.8
TRT2	1203	3753	32.1
TRT3	1350	4006	33.7
TRT4	1178	3265	36.1
TRT5	1210	3763	32.2
AFC	1261	3817	33.0

FUTURE PLANS: The experiment will be repeated in 1992 with cotton being grown on both fields. Similar procedures will be used in the harvest.

WATER QUALITY MANAGEMENT WESTSIDE OF SAN JOAQUIN VALLEY--BRITZ PROJECT IV. TOMATO YIELD

J.E. Ayars, C.J. Phene, H.I. Nightingale, R.A. Schoneman, B. Meso and F. Dale

OBJECTIVES: Compare the yield response of tomato to subsurface drip irrigation and to yields from furrow irrigation.

PROCEDURES: The tomatoes were planted on 66" bed with two rows per bed (approximately 1 lb of seed per acre) starting March 11, 1991 and emergence was observed by March 23, 1991. Approximately, 8 inches of water was applied by sprinkler for germination following planting of the tomatoes.

The tomato plots were hand-sampled for yield prior to beginning the machine harvest. Three replicate samples were taken at the head end (H) and tail end (T) of each plot. A total of 20 feet of bed was harvested and the weights of large (LRF) and small (SRF) red fruit and large (LGF) and small (SGF) green fruit and limited (LTD) use fruit were determined by stripping all the tomatoes from the plants and sorting them into appropriate classes. The average yield for the plot as well as the average for each end was calculated. Red fruit samples were taken to a commercial grading station for BRIX analysis. An FMC mechanized tomato harvester operated by Britz personnel was used for machine harvesting. Machine harvested yields were calculated by filling a set of trailers, measuring the weight of load and determining the area required to fill the trailers. Machine harvested yields were available in Treatments 6 and 9 of the drip plots and the furrow irrigated plots east of the drip plots. These yields were compared to the average yield calculated from the hand sampling from each plot.

RESULTS: The hand harvested yields for the head and tail end of each plot are summarized in Table 1 and Figures 1 and 2. The data in Figure 1 show the average hand harvested yields of large red fruit (LRF) for each of the irrigation systems. The yield in the surface irrigation systems (NCO, NCF, AFA) averaged approximately 10 tons per acre less than the drip plots (TRT 6-10). The components of the total hand harvested yield are given in Figure 2. There is still approximately a 10 ton per acre difference between the furrow irrigated and drip irrigated plots. It is apparent that the drip plots consistently out-produced the furrow irrigated plots.

The data in Table 1 demonstrate the effect of irrigation non-uniformity in both the drip and furrow plots. With the exception of treatment 10, the yield was reduced from the head to the tail end of the field which could be an indication that the tail end received less water than the head end of the field. There was an 8% reduction in yield from head to tail in the SDI plots compared to a 22% reduction in yield in the furrow irrigated plots.

Table 1. Summary of hand harvested total tomato fruit yields Britz.

	Total Yield (tons/acre)		Single Fruit weight
Plot	Head of field	Tail of field	oz (g)
NCO	54.34	44.51	1.94 (55.3)
NCF	53.92	43.65	2.00 (56.9)
AFA	57.18	40.99	2.10 (59.2)
TRT 6	62.22	55.20	2.14 (60.7)
TRT 7	63.21	54.06	2.17 (61.7)
TRT 8	64.54	58.54	2.33 (66.2)
TRT 9	59.63	55.16	2.33 (66.2)
TRT10	55.57	56.94	2.31 (65.6)

The average hand harvested total fruit yield for the furrow irrigated plots was 49.1 tons per acre while the average for the drip plots was 58.5 tons per acre. There were two areas where it was possible to compare machine harvested yields with hand harvested total yields. In the plots (AFA) east of the drip system the yield was compared to the yield in drip plots 9 and 6 (Figure 3). In this instance, the machine harvested yields were 29 and 38 tons per acre in furrow plots compared to 49 and 61 tons per acre in the drip system. The 20 and 23 t/acre differences were in part due to the severe stand problems and to irrigation uniformity problems which existed in the furrow plots.

The average fruit size was compared in drip and furrow irrigated plots. The data show an average fruit weight of 2 oz (57 g) and 2.25 oz (64 g) in the furrow and drip plots, respectively. Another important parameter in the yield consideration is the concentration of soluble solids in the fruit. In general, a soluble solid concentration of around 5° BRIX is considered acceptable for processing. Fruit samples were taken at harvest and tested at a commercial weigh station. The average °BRIX for the hand sampled furrow and SDI plots was 5.4 and 4.8, respectively. These values increased further prior to machine harvest. BRIX values of the machine harvested plots were 5.5 and 5.4 for the furrow and drip irrigated plots, respectively.

FUTURE PLANS: The experiment will be repeated with tomatoes as soon as possible. It will depend on the availability of water from the Westlands Water District. These data will be used in a presentation.

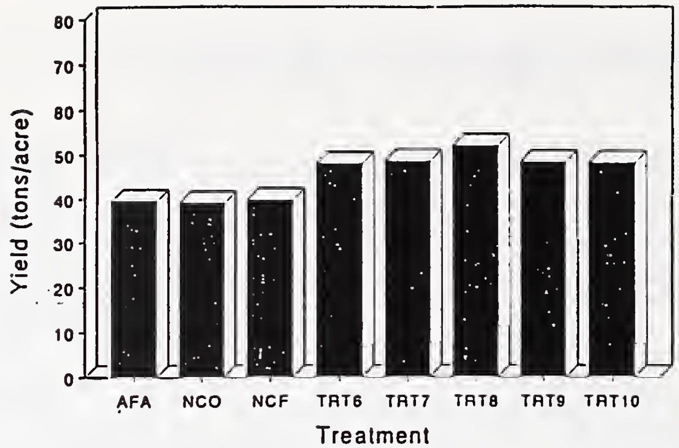


Figure 1. Average 1991 hand harvested large red tomato fruit yield at Britz research site.

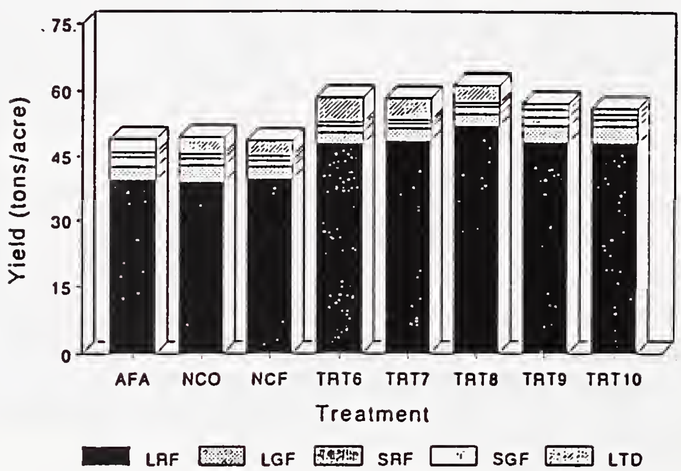


Figure 2. Average 1991 yield of all hand harvest components at Britz research site where LRF is large red fruit, LGF is large green fruit, SRF is small red fruit, SGF is small green fruit and LTD is limited use fruit.

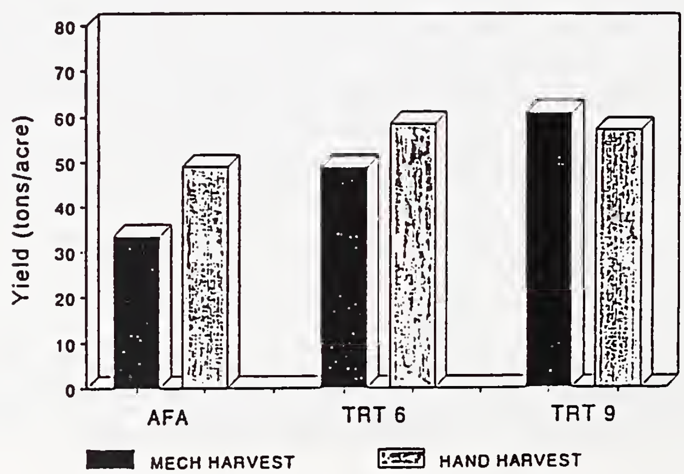


Figure 3. Comparison of total hand and machine harvested yields for drip plots (TRT 6, TRT 9) and the furrow irrigated plot (AFA) east of the drip plots.

WATER QUALITY MANAGEMENT WESTSIDE OF SAN JOAQUIN VALLEY-- BRITZ PROJECT V. WATER BALANCE CALCULATIONS

J.E. Ayars, C.J. Phene, H.I. Nightingale, R.A. Schoneman, B. Meso and F. Dale

OBJECTIVES: Determine water balances for both the cotton and tomato crops.

PROCEDURES: The water applied by the drip system was measured by flow meters installed in each treatment. The water applied to the furrow plots was estimated using time and flow to each of the treatments. This data was difficult to obtain. The crop water use was estimated for the cotton using a production function which estimated water use as function of lint yield. The tomato water use was estimated based on yield also.

RESULTS: The applied water was compared to the calculated evapotranspiration (ET) of the tomato crop. A germination irrigation of 7.7 in. was applied in addition to a rainfall of 5.6 in. which fell in February and March. Including rain and germination irrigation the total water applied to each plot was estimated to be 28, 27, 29, 29 and 29 inches in the drip treatments 6, 7, 8, 9, and 10 respectively. The total furrow irrigation was estimated to be 30 inches and the estimated ET for the crop was 30 inches. The irrigation records were not adequate for the furrow irrigation to permit more than an estimate to be made.

Based on research data with UC-82B comparing yield to evapotranspiration, the drip plots could require on the order of 27 inches of water to produce a crop yield equivalent to what was found in this experiment. The applied water data for the drip plots was estimated to be approximately 27$\pm$2 inches. The lower yields in the furrow plots indicated that all the applied water was not available and there was the potential for the loss of water to deep percolation under the furrow plots.

The applied water was summarized for all cotton treatments in Table 1. Crop evapotranspiration (Et_c) was estimated for the cotton by using the potential Et_p from the CIMIS station located at Murrieta Farms and multiplying it by a crop coefficient (Et_c CIMIS in Table 1) and by using a production function (Et_c yield in Table 1) for lint yield and crop water use which was developed by Don Grimes. The cotton used approximately all of the water supplied when the water use is calculated based on the yield instead of using the CIMIS weather data and crop coefficient. It is important to note that much of the water was supplied prior to the time that it was required for crop water use. Nearly 50% of the water was supplied as rainfall and pre-plant irrigation before the crop was planted. This water was stored as shallow groundwater which then had to be extracted by the cotton later in the season.

Table 1. Summary of water applied to 1991 cotton crop at Britz site.

	TRT1	TRT2	TRT3	TRT4	TRT5	Surface
Pre-plant(in)	7.7	7.7	7.7	7.7	7.7	7.7
Rain(in)	5.6	5.6	5.6	5.6	5.6	5.6
Season	8.6	10.8	10.2	10.5	10.5	11.1
Total (in)	21.9	24.1	23.5	23.8	23.8	24.4
Et_c calc CIMIS(in)	19.4	19.4	19.4	19.4	19.4	19.4
Et_c calc yield(in)	23.6	22.0	24.0	21.7	22.1	23.3

FUTURE PLANS: Water meters have been purchased and the flow to each furrow irrigation treatment can be measured. Water table observation wells have been installed throughout the site to monitor the groundwater response and neutron access tubes have also been installed in each site. This equipment will enable us to develop a better picture of the water balance in each field and under each treatment.

WATER QUALITY MANAGEMENT WESTSIDE OF SAN JOAQUIN VALLEY--BRITZ PROJECT VI. WATER QUALITY

J.E. Ayars, C.J. Phene, H.I. Nightingale, R.A. Schoneman, B. Meso and F. Dale

OBJECTIVES: Determine the impact of irrigation management on groundwater quality.

PROCEDURES: Observation wells were installed in the cotton field late in the season and were sampled on a weekly basis. The depth to groundwater was also measured at this time.

RESULTS: Because of the problems encountered with the initial installation of the system and with the startup of the drip system, only a few wells were installed this year. Water quality data were taken for the water being pumped from the deep well being used for furrow irrigation, for water from the Westlands irrigation district and the shallow groundwater. The electrical conductivity (EC), boron concentrations and chloride concentrations were determined for each water source. These data are shown in Figures 1 to 3, respectively. The shallow groundwater was the poorest quality water. The EC of the well water and Westlands water remained constant during the irrigation season as did the shallow groundwater. The boron concentration in the shallow groundwater increased during the growing season while remainig constant in the irrigation supply.

FUTURE PLANS: Observation wells will be installed in each treatment and around the perimeter of the site for use in collecting water samples. Each well will be sampled weekly during the growing season and monthly thereafter.

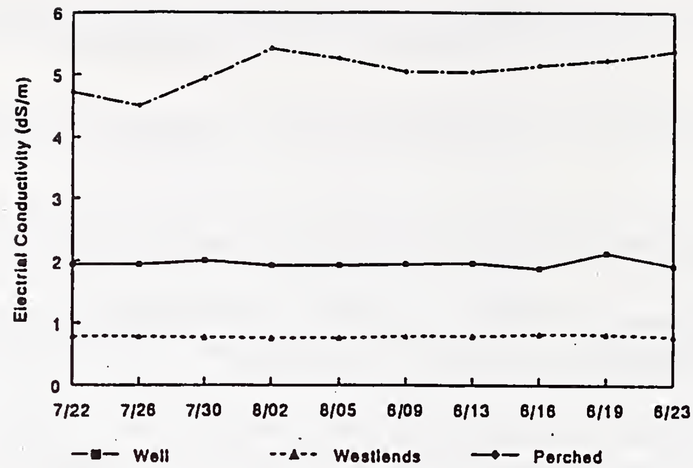


Figure 1. Electrical conductivity in irrigation well, Westlands water supply and perched groundwater at Britz research site in 1991.

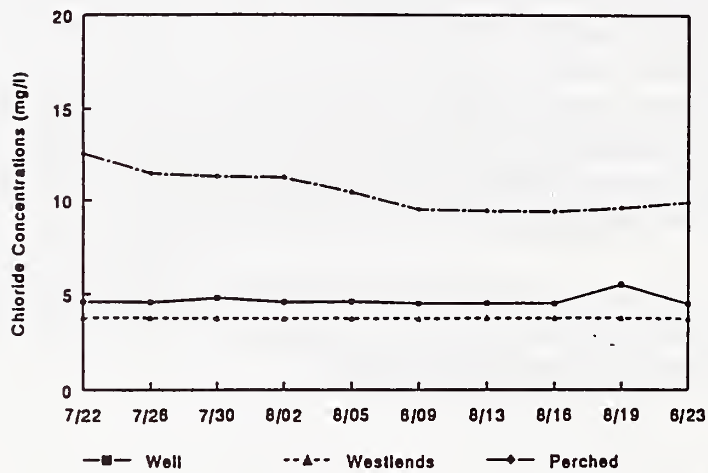


Figure 2. Chloride concentration in irrigation well, Westlands water supply and perched groundwater at Britz research site in 1991.

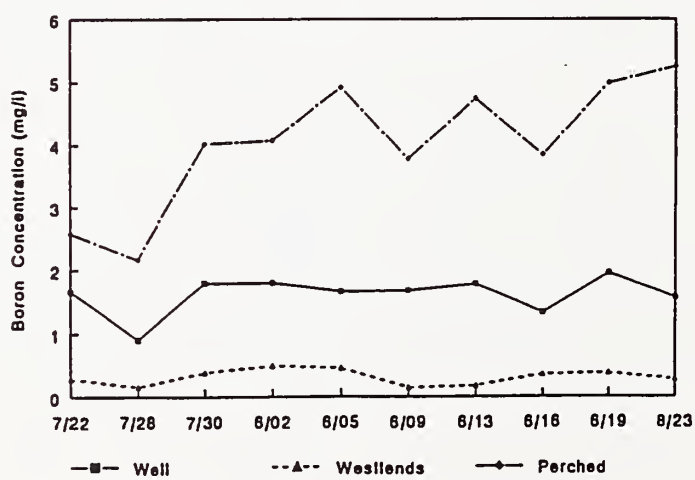


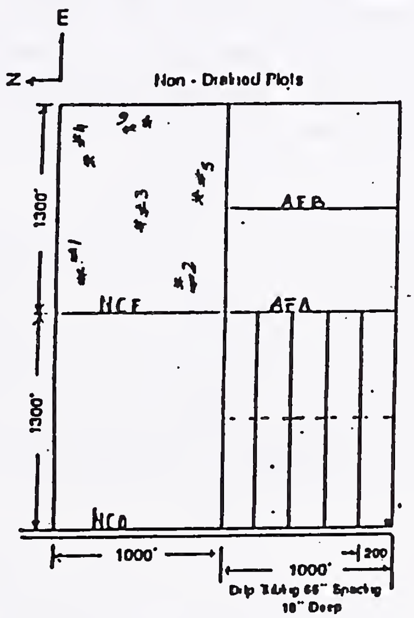
Figure 3. Boron concentration in irrigation well, Westlands water and perched groundwater at Britz research site in 1991.

EARLY DEATH OF TOMATO PLANTS OBSERVED IN THE PLOT NCF BRITZ PROJECT 1991

M.K. Beta, R.A. Schoneman, J.W. Penland, F. Wong and J.E. Ayars

OBJECTIVES: To determine the causes of plant death and to find alternative solutions which can respond to future vegetative growth.

PROCEDURES: NCF is located in the northeast section of the field in the Britz experimental project where, like the rest of the field, tomatoes were grown. A furrow irrigation system was used. In mid season, necrotic plants were found in an area covering more than two acres. No pronounced symptoms of damage or deficiencies had been observed prior to this time. The irrigation and fertilizer were applied in the same manner as the rest of the field in the non-subsurface drip irrigation plots (NCO, AFA, AFB). Tomato plants in this affected area showed good vigor and heavy fruiting, but in general the vines and fruits were smaller than normal.



During the peak vegetative period between mid-July and the beginning of August, the plants began dying, leaving their early reddish matured fruits on the dried vines in good condition and showing no signs of damage. A close look over the entire non-drained plots was done, and soil samples taken in the affected area and the surrounding areas for laboratory analysis. Our contact with ranch the manager led us to discover that this problem had been observed in past years. Attempts to improve the soil condition in this section had so far proved unsuccessful. These attempts had included good soil preparation, increase of fertilizers and lime application. During our survey we observed a high water table level (150 cm average) and poor water drainage in this location. Water stagnation in the furrows and in the tail water drainage ditch could be found many days after the irrigation was applied. Scalding and low concentration of oxygen in the root zones might also have contributed to the tomato plant injuries in the hot summer season.

<u>RESULTS</u>: Salinity stress depends on the salt content of the applied water, the soil and the ground water; on water table elevation, crop tolerance and water management.

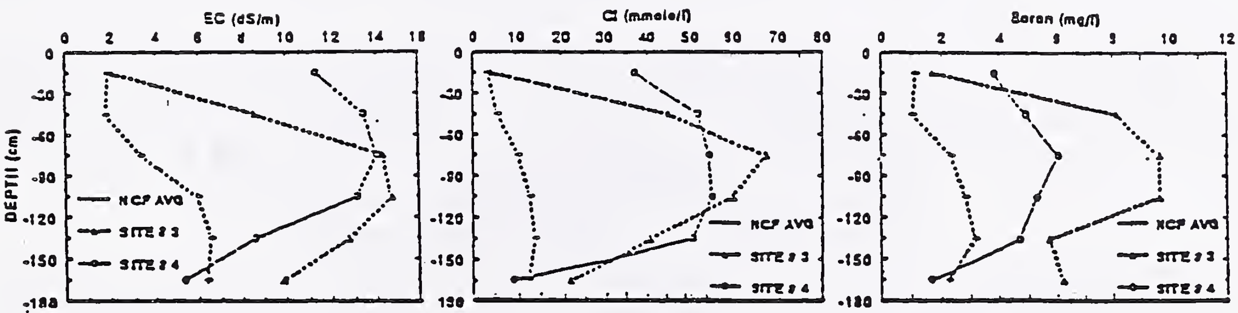
The results of the laboratory analyses revealed an excessive concentration of Boron and soluble salts in the soil and in the ground water samples, thus, a high level of salinity was observed. The ratio of EC and SAR showed values that exceeded the tomato threshold.

Tomatoes are a moderately salt tolerant crop. The plant is more sensitive in the early seedling stage than during the late vegetation stages. An excessive accumulation of soluble salts may harm tomato plants. Thus, it is believed that the concentration of Boron and the soluble salts caused the observed plant deaths.

<u>FUTURE PLANS</u>: Based on the results of the laboratory analyses, good water quality is recommended for irrigation. The use of ground water requires good water management, and should be used in small amounts with appropriate seasonal crops to limit the accumulation of salts in the root zone. Considering the water table level in the area, a long term use of ground water in large amounts will only increase the concentration of hazardous mineral elements in the soil and in the water table profile. Therefore, a selection of salt-tolerant crops will be necessary in the area. Leaching and reclamation or the practice of drainage are recommended after a long term use of excessive ground water for irrigation.

BRITZ PROJECT 91 VALUES OF SOIL SAMPLES (NCF-SECTION)

SAMPLES #	DEPTH cm	EC25C ds/m	Cl m.mol/l	SO4 mg/l	NO3 mg/l	B mg/l	K mg/l	Na mg/l	Ca mg/l	Mg mg/l	SELENIUM mg/l	SAR meq/l
1	0-90	2.39	7.65	40.22	23.77	1.35	20.53	338.80	162.22	20.15	9.24	6.89
2	0-90	1.99	4.32	14.91	31.20	1.39	17.38	282.13	135.77	16.26	7.04	7.06
3	0-90	8.29	38.75	45.64	84.07	6.48	28.31	1572.67	513.03	51.06	5.14	16.01
4	0-90	12.91	47.76	109.51	20.60	4.93	27.64	1769.48	877.33	68.43	80.78	17.33
5	0-90	2.64	7.76	18.16	26.60	1.71	18.10	407.52	148.71	17.71	9.50	8.15
8	0-90	1.33	3.34	8.75	4.87	1.01	24.00	170.88	94.23	12.45	1.00	4.69
Avg :	0-90	4.93	18.26	39.20	31.85	2.81	22.68	756.91	288.55	31.01	18.78	10.02
1	0-90	4.96	8.62	62.27	9.10	1.84	24.51	652.67	798.00	42.49	26.58	6.09
2	0-90	5.39	8.52	34.24	12.73	2.29	20.88	916.75	561.83	39.63	32.44	10.50
3	0-90	12.42	40.80	107.48	33.90	7.20	28.05	2532.33	689.17	74.20	52.83	24.44
4	0-90	9.01	38.25	48.48	111.23	3.88	34.70	1603.17	667.33	59.28	58.76	15.96
5	0-90	8.45	22.63	32.48	20.97	4.08	26.14	1527.17	700.33	65.47	37.93	14.79
8	0-90	1.40	3.98	7.96	8.73	1.34	8.55	240.86	54.86	3.63	4.11	8.57
Avg :	0-90	6.94	20.47	48.82	32.44	3.44	23.81	1245.49	578.59	47.45	35.44	13.39
1	0-90	3.68	8.14	51.25	16.43	1.60	22.52	495.73	480.11	31.32	22.18	6.49
2	0-90	3.69	6.42	24.57	21.97	1.84	19.13	599.44	348.80	27.95	26.09	8.78
3	0-90	10.35	39.78	76.55	58.98	6.84	28.18		601.10	62.63	33.75	20.23
4	0-90	10.96	43.01	78.99	65.90	4.40	3.17	1686.33	672.33	63.86	69.76	16.65
5	0-90	8.50	15.19	25.32	23.78	2.90	22.12	967.34	424.52	41.59	23.71	11.47
6	0-90	1.37	3.66	7.36	5.80	2.36	16.28	205.87	74.55	8.04	2.56	6.63
Avg :	0-90	6.43	19.37	44.01	32.14	3.32	18.57	659.12	433.57	39.23	29.68	11.71



GROUND WATER QUALITY INVESTIGATION
TOTAL AVERAGE OF WATER QUALITY

SAMPLES	EC25C ds/m	Cl meq/l	S04 meq/l	B mg/l	NO3 mg/l	Mo mg/l	K mg/l	Na mg/l	Ca mg/l	Mg mg/l	SELENIUM ug/l
GW	1.95	4.41	12.2	1.63	0.29	0.05	3.43	377.58	53.93	4.46	0.88
SW	0.78	3.35	3.68	0.33	0.37	0.04	5.25	102.88	60.56	15.22	0.47
PW	4.65	9.9	35.78	3.65	15.99	0.07	17.53	741.98	273.54	86.8	8.26

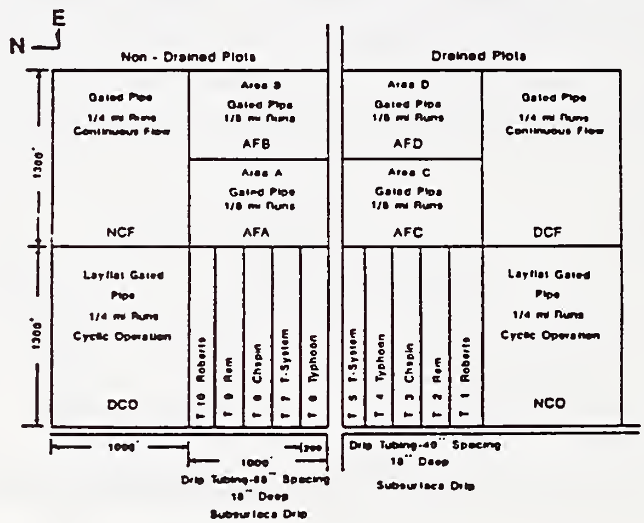
SUMMARY OF THE MOST IMPORTANT PROBLEMS EXPERIENCED IN THE APPLICATION OF THE SUBSURFACE DRIP IRRIGATION (BRITZ PROJECT)

M.K. Beta, R.A. Schoneman, F.Dale, J.W. Penland,
F. Wong, and J.E. Ayars

OBJECTIVES: To locate the source and cause of the problems observed with subsurface drip irrigation in the research field, and determine methods of overcoming future obstacles.

PROCEDURES: The total field area of the experiment was 60 acres. Five types of drip tubing with variable dimensions were used: Roberts, Ram, Chapin, Typhon, and T-system.

The first test of the system and its application were done on May 31, 1991. The application in the subsurface drip irrigation was applied in the north block: treatments six to ten. The section was closely monitored to detect any possible leaks and damage in the subsurface drip lines.



RESULTS: Following the complete installation of the system and its full application in service, several major and minor problems were observed, they were: total disconnection of the joints (drip tube couplings), connectors or coupling loose, chewing and bursting of tubing, and tubing damage such as cuts and holes.

The first major problem was the disconnection of the drip tube couplings. This was a general problem found over all the treatments and was thought to be due to incorrect adjustment of the pressure regulator. This produced high water pressure into the drip lines causing the total separation of the couplings in the lines. A secondary factor contributing to the problem was probably less suitable work done by crew workers installing the drip tubing. The crew barely adjusted the fittings on the drip lines which easily gave under water pressure in certain cases.

The second problem observed in all treatments, was the connectors or tube couplings loose between the riser tubing and the subsurface drip line. This problem was found at the head of the rows, in the middle of the field, and at the end of the rows. In connection with the

problem, minor leaks were observed and certain leaks needed to be repaired. The cause could be related to careless work during the installation of the system in the field.

The third major problem consisted in the chewing and perforation of the subsurface drip tubing. In some cases the findings were attributed to the work crew and the machines while installing the drip lines. Our major concern was the damage caused by the presence of the gopher colonies around certain sections of the field. The colonies were found in plots 1, 2, 7, 8, and were also observed in the DCO and AFD plots. The damage caused by the gophers was alarming especially in treatments 1 and 2. If nothing is done to eliminate the problem we can expect more damage in the coming seasons.

The bursting of the drip tubing was a major, but temporary problem. The bursting of the drip lines occurred in treatment 1 with the Roberts drip tubing type. The bursts were probably caused by valve malfunction in the system which produced high pressure in the drip lines. The bursts occurred between the riser tubing and the drip lines at the head of the rows and, also in the open location in the trenches where the tubing were exposed for repairs. Several lines burst in plot 1 before the valve was repaired and adjusted. Contrary to treatment 1, we didn't observe similar damage in treatment 10 which also carries the same type of tubing: "Roberts".

The last and minor problem consisted of finding cuts and holes in the drip lines. The damage was found in most of the treatments. These defects could be related to the work crew or to the machines and tools used to perform work in the trenches.

FUTURE PLANS: At the present time, my first recommendation is to eliminate the gopher colonies, either by injecting poison into the subsurface drip lines or by the use of a manual (mechanical) poisonous probe tool. The winter months are the most appropriate time for the application, as it would allow time for a good survey and observation of the effective reaction of the chemical product and, if needed, time for reapplication.

Secondly, one of the major problems we faced last season was the pressure regulation of the valves in the system. We installed a new pump system which will deliver a high volume of water, consequently increasing the water pressure. My concern is to know in advance, what will be the impact over the system and especially on the valves' function. Prior to a general testing before the season, it will be very important in overseeing all former problems.

Good observation of the drip tube coupling fittings will be needed in the next season. Our goal will be to find effectiveness-to-adapt to different conditions and pressures exercised in the various tubing. One question needs to be answered: Is the coupling looseness due to the manufacturing or a simple fact of carelessness?

Types of tubing and the main problems observed in the experimental field:

Plot	Tubing type	Disconnection	Coupling Loose	Chewing	Cut	Hole	Explosion	Total
TRT1	Roberts	2	-	7	3	-	8	20
TRT2	Ram	3	3	2	2	2	-	12
TRT3	Chapin	3	2	1	1	1	-	8
TRT4	Typhon	2	2	-	2	2	-	8
TRT5	T-system	4	3	1	3	2	-	13
TRT6	Typhon	6	1	-	4	-	-	11
TRT7	T-system	1	1	1	2	1	-	6
TRT8	Chapin	2	-	1	2	2	-	7
TRT9	Ram	5	4	-	-	2	-	11
TRT10	Roberts	2	2	-	3	1	-	8
Total		30	18	13	22	13	8	104

CRIS 13000 003

MEASUREMENTS IN SMALL WEIGHING LYSIMETERS: EFFECTS OF GROUNDWATER SALINITY ON ET RATES, WATER USE FROM SHALLOW GROUNDWATER: EXPERIMENTAL PROCEDURES

R.B. Hutmacher, J.E. Ayars, S.S. Vail, R.A. Schoneman,
G. Cardon, D. Dettinger, A. Bravo

<u>OBJECTIVES</u>: To determine the influence of shallow groundwater salinity on crop water use from shallow groundwater and resulting plant responses, including dry matter, harvestable yield, and plant chloride uptake.

<u>PROCEDURES</u> Small weighing lysimeters constructed of 45 cm diameter, 150 cm long PVC pipe were used as above-ground lysimeter columns. PVC end caps were glued on the bottom of each lysimeter and tubing was connected to a reservoir modified to act as a large volume Marriotte bottle, thereby allowing it to act as both a reservoir and a method to maintain a constant groundwater level. Two Marriotte bottles were instrumented with pressure transducers and thermocouples to evaluate the influence of diurnal temperature fluctuations on internal pressures and operation of the Marriotte bottle system.

Hydraulic pillows filled with water and connected to manometers were used to calculate weight changes and evapotranspiration (ET) rates for each of the columns. Hydraulic pillows were constructed from 35 cm diameter, flexible PVC "layflat" water discharge hose which was glued and clamped with metal straps to form a water-tight pillow. All of the hydraulic pillows were calibrated against known weights within the normal range of operating weights expected during each season. Weight changes determined with the manometers were used to determine the amount of irrigation water needed to refill the soil water used during each irrigation cycle. In all cases, non-saline water was used for irrigation and was applied at the soil surface of each column.

Crop ET and water use from the shallow groundwater were calculated once per week. These calculations were based on changes in lysimeter weight and water use from the Marriotte reservoirs between each measurement date. Nonsaline irrigation water (0.3 dS/m) was applied at the soil surface of each lysimeter in amounts adequate to replenish soil water use (calculated from column weight change) since the prior measurement date. An additional 4 to 8 L of irrigation water was added to treatment T1 (see below for treatment descriptions) on the fourth day of each weekly irrigation cycle to avoid severe plant water deficits in this specific treatment, which had no access to shallow groundwater.

Four columns were filled with soil, were not planted with crops, and were capped to eliminate weight loss by evaporation. These non-evaporating lysimeters were used to account for temperature effects on manometer readings, and all other manometer readings were adjusted accordingly. With this system, measurement resolution was adequate to determine crop ET and use from the groundwater every two to three days. In practice, weekly average values were determined in all three crops.

In 1990, one study involving 28 column lysimeters was conducted. The free water surface of the groundwater was maintained at a level of 120 cm below the ground surface. The columns were packed with a clay loam soil to more closely approximate the type of soils prevalent in the drainage problem areas of much of the western San Joaquin Valley. Prior to

and following the 1990 season, the soil in the columns was thoroughly leached to return the columns to a non-saline condition.

In order to account for the different salt tolerance of a range of crops in this study, the groundwater treatment salinity levels have been keyed as multiples of the "threshold" salt tolerance limits for each crop as identified by Maas and Hoffman (as shown below):

Table 1. Shallow groundwater treatments in short columns (120 cm groundwater depth in cotton in 1990 and 1991.

Treatment #	Groundwater Imposed (Yes/No?)	Groundwater Treatments	Specific Groundwater Salinity ($dS\ m^{-1}$)
1	No	no groundwater	-
2	Yes	non-saline	0.3
3	Yes	1 times threshold [a]	7.7
4	Yes	2 times threshold	15.4
5	Yes	3 times threshold	23.1
6	Yes	4 times threshold	30.8

[a] Crop-specific threshold salinity for cotton yield response as described by Maas and Hoffman, 1977. "Crop salt tolerance - current assessment". J. Irr. Drain. Div. Am. Soc. Civil Eng. 103(IR2):115-134.

The salts used to prepare the different salinity levels in the groundwater were in all cases produced by a half-half mixture of sodium chloride and calcium chloride. Low boron content salts were used to eliminate interactions between crop responses to simple salts versus contaminating elements. All lysimeter columns were fertilized with equal amounts of a modified Hoaglands solution on a weekly basis, with the fertilizer added to the top of the columns along with each irrigation.

In 1991, in addition to the above-listed treatments, cotton was also grown in eight columns 2 m in length. Treatment T3 and T4 were imposed on four columns each, with the free water surface set at 180 cm below the soil surface in the column. These columns were used to identify the magnitude of crop response to a greater depth to shallow groundwater.

In between each crop, the soil in the upper 45 cm of each column was replaced. Soil samples were collected in 15 cm increments to a depth of 120 cm in each column prior to and at the end of each experiment to allow characterization of the changes in soil EC, pH, and sodium, calcium, and chloride levels.

Cotton (var. GC510) was planted in 4 L containers on calendar day 127 (1990) and 117 (1990) and transplanted to the columns on day 143 (1991) and 135 (1991). Irrigation was terminated during September in both years, the crops were sprayed with defoliant and hand harvested for above-ground dry matter and seed cotton yields. Total rainfall during the experiment was 36 mm in 1990 and 21 mm in 1991.

MEASUREMENTS IN SMALL WEIGHING LYSIMETERS: EFFECTS OF GROUNDWATER SALINITY ON EVAPOTRANSPIRATION, SHALLOW GROUNDWATER USE, AND SOIL SALINITY

R.B. Hutmacher, J.E. Ayars, S.S. Vail, R.A. Schoneman,
G. Cardon, D. Dettinger, A. Bravo

OBJECTIVES: To determine the influence of shallow groundwater salinity on crop water use from shallow groundwater and resulting plant responses, including dry matter, harvestable yield, and plant chloride uptake.

PROCEDURES: Operational procedures were as described in the previous report (see "Measurements in small weighing lysimeters: Effects of groundwater salinity on ET rates, water use from shallow groundwater: Experimental procedures"). The groundwater treatments were as follows: T1, no groundwater; T2, nonsaline (0.3 ds/m groundwater; T3, 7.7 dS/m groundwater; T4, 15.4 dS/m groundwater; T5, 23.1 dS/m groundwater; T6, 30.8 dS/m groundwater. All 6 treatments were represented in the "short" (120 cm groundwater depth) columns, while only treatments T3 and T4 were included in the "tall" (180 cm shallow groundwater depth) columns. Only the short columns were used in 1990, while both tall and short columns were used in 1991.

Cotton was germinated in 4L containers and transplanted 10 to 15 days later to the columns. Soil in the columns during both years was a Panoche clay loam soil collected from the surface soil layers at the West Side Field Station. Upper canopy fully-expanded leaves and stem sections from the top 5 and second 5 nodes were collected two weeks prior to final harvest to evaluate plant chloride accumulation as a function of shallow groundwater treatments. The following parameters were measured at harvest: vegetative dry weight, boll dry weight, lint dry weight, and seed weight. Soil samples were collected post harvest in 15 cm increments to a depth of 105 cm in the short columns and to 165 cm in the tall columns to determine the influence of shallow groundwater use and salinity on soil profile salinity, cation and chloride distribution.

RESULTS: Crop ET and Shallow Groundwater Use. During both years of the study, cotton in treatments T2, T3, and T4 tended to have mid-to late-season weekly evapotranspiration (ET) rates which were 5 to 17% higher (depending on the time of year) than in treatments without groundwater (T1) or treatments with more saline groundwater (T5, T6) (data not shown). The reason for the reduction in weekly transpiration rates was greater water stress and reduced availability of alternative water supplies when soil water was depleted (in treatments where either no supplemental water was available (T1) or where groundwater use was suppressed by groundwater salinity (T5, T6); see Figure 1).

Crop shallow groundwater use was significantly influenced by the salinity of the shallow groundwater (Fig. 1). Beginning on day 201 in 1990, treatments T2, T3, and T4 had a significantly higher percentage of total ET derived from shallow groundwater than in treatments T5 or T6. In the period ending on day 253 in 1990, the mean contribution of

shallow groundwater to season total ET ranged from a high of 55.4% (T2) to a low of 18.4% (T6).

Similar patterns of groundwater use were observed during the 1991 season (data not shown). The response of cotton plants to groundwater depth (in the tall columns versus shorter columns) was in the timing and magnitude of groundwater use. The same general seasonal patterns of water use were observed in tall and short columns, however, the greater depth to groundwater resulted in a 7 to 14 day lag in early season use of shallow groundwater in treatments T3 and T4 (the only treatments represented in tall columns) and a 10 to 15% average reduction in the percentage of ET supplied by the saline groundwater (data not shown). This difference in relative shallow groundwater contribution to ET persisted throughout the season, being evident in both mid- and late-season.

Salinity, Cation, and Chloride Distribution in Soil. In most cases, significant increases in salinity, chloride and cation distribution relative to the surface soil concentrations or concentrations in treatment T1 or T2 began at the 45 to 60 cm depth (data not shown). Soil EC, Cl^-, and cation concentrations in the 45 to 75 cm depth were generally highest in treatments T3 and T4, while concentrations in the 75 to 105 cm depth were higher in treatments T5 and T6 than in T3 and T4. Apparently, higher shallow groundwater use in T3 and T4 moved more salts into the upper profile, and with minimal leaching practices, significantly higher salt accumulations occurred. Similar trends were observed in both years.

FUTURE PLANS: When soil samples collected from the 1991 cotton are analyzed, the data from both years of the cotton experiments and prior tomato and wheat experiments will be summarized and a manuscript prepared.

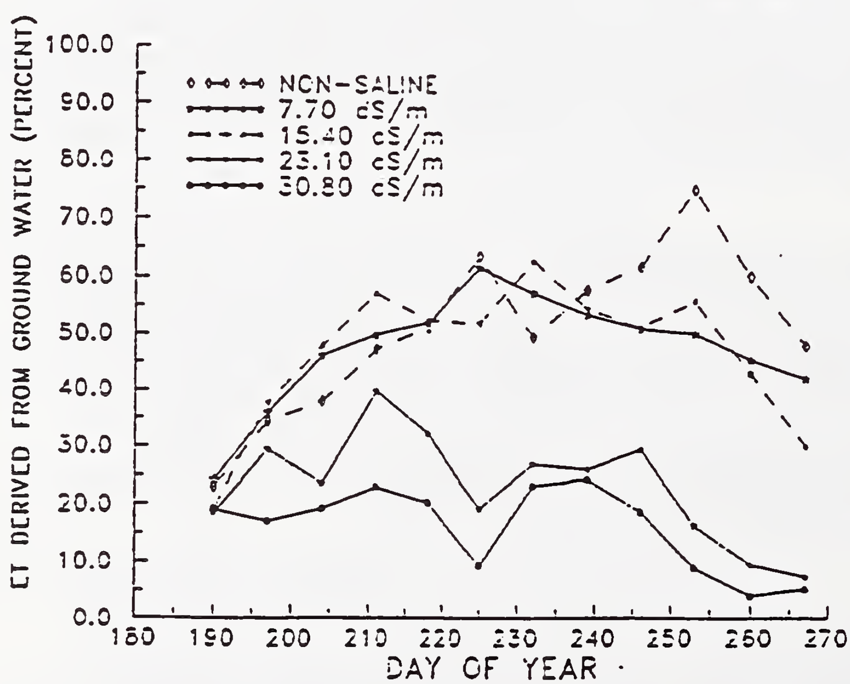


Figure 1. Percent of weekly crop evapotranspiration (ET) derived from shallow groundwater for column lysimeter-grown cotton in Fresno, CA in 1990 as a function of salinity of shallow groundwater.

MEASUREMENTS IN SMALL WEIGHING LYSIMETERS: EFFECTS OF GROUNDWATER SALINITY ON COTTON GROWTH AND YIELD, CHLORIDE UPTAKE, AND ROOT DISTRIBUTION

R.B. Hutmacher, J.E. Ayars, S.S. Vail, R.A. Schoneman, G. Cardon, D. Dettinger, A. Bravo

OBJECTIVES: To determine the influence of shallow groundwater salinity on crop water use from shallow groundwater and resulting plant responses, including dry matter, harvestable yield, and plant chloride uptake.

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In 1990, soil cores were collected at a position midway between the column outer wall and center, with the cores separated into 30 cm increments representing depths of 0-30 cm, 30-60 cm, 60-90 cm, and 90-120 cm in each column. Soil samples were washed in a dilute acetic acid solution, roots separated by hand from soil, and dried at 50 C for 48 hours. Root distribution data was expressed as g root dry weight kg^{-1} soil dry weight.

RESULTS: Plant chloride uptake. Analysis of composite samples prepared using leaves (fully expanded, nodes 16 to 18), showed the mean chloride concentration to range from a low of 168 mmol kg^{-1} dry weight (T1, no groundwater) to a high of 767 mmol kg^{-1} dry weight (T5). Treatment T6 had a mean concentration of 454 mmol kg^{-1} dry weight, with the relatively lower Cl^- concentration perhaps reflecting the low percentage of saline groundwater use. Stem Cl^- data exhibited treatment effects similar to those observed in leaf tissue. Upper stem chloride concentrations were lower than in leaves, with the mean ranging from 47 mmol kg^{-1} dry weight (T2) to a high of 240 mmol kg^{-1} dry weight (T5).

Dry weight and seed cotton yields. Seed cotton yields were significantly affected by shallow groundwater treatments in both 1990 and 1991 (Table 1). The highest late-season total dry matter and seed cotton yields in 1990 were in treatments T1, T2, and T3, with significantly higher values than in T4, T5, and T6. Plants in 1990 were consistently smaller than in 1991, when a much better boll set was achieved. Reasons for the difference are not fully explainable, although insect pressure was significantly lower in 1991 than in 1990. Yields in 1990 and 1991 were roughly correlated with relative treatment differences in ET (see report "Measurements in small weighing lysimeters: Effects of groundwater salinity on ET, shallow groundwater use, and soil salinity").

Table 1. Above-ground dry matter at boll harvest and seed cotton yields of column lysimeter cotton plants as a function of shallow groundwater treatments in Fresno, CA in 1990 and 1991.

Year	Shallow Groundwater Depth (m)	Trt.#	Dry weights (kg m^{-2}) Stems+ Leaves [a]	Seed Cotton + burs	Total Above-ground
1990	1.2	T1	.77	.84	1.61
	1.2	T2	.82	.88	1.70
	1.2	T3	.76	.77	1.53
	1.2	T4	.72	.71	1.43
	1.2	T5	.65	.73	1.38
	1.2	T6	.64	.60	1.24
1991	1.2	T1	.70	2.08	2.78
	1.2	T2	.74	2.08	2.82
	1.2	T3	.79	1.88	2.67
	1.2	T4	.79	1.93	2.72
	1.2	T5	.72	1.81	2.53
	1.2	T6	.66	1.75	2.41
	1.8	T3	.91	2.06	2.97
	1.8	T4	.84	1.93	2.77

[a] Sampling was done after defoliant was applied, resulting in loss of most leaves prior to this measurement. Result is that most of weight shown is stems.

Root dry weights. Of the four treatments monitored for shallow groundwater, total root mass was significantly lower only in treatment T6 (Table 2). Treatments which had significantly higher shallow groundwater uptake (T2, T4) than T1 and T6 had significantly higher root mass in the 60-90 and 90-120 cm depths in the soil columns (Table 2). Treatments T1 and T6 had less than 16% of their total root mass in the lower 60 cm of the profile, while treatments 32% and 25% of the root mass was in the lower 60 cm in treatments T2 and T4, respectively.

Table 2. Root dry weight distribution in lysimeter-grown cotton in 1990 as a function of shallow groundwater treatment.

Treatment	Depth in soil column sampled for roots (cm) 0-30 cm (g m^{-3})	30-60 cm (g m^{-3})	60-90 cm (g m^{-3})	90-120 cm (g m^{-3})	Total
T1	4490	3700	1180	330	9700
T2	2970	3930	2330	860	10090
T4	3760	2870	1760	970	9360
T6	3700	3530	940	260	8430

FUTURE PLANS: When soil samples collected from the 1991 cotton are analyzed, the data from both years of the cotton experiments and prior tomato and wheat experiments will be summarized and a manuscript prepared.

LOAD FLOW STUDIES I: SALT LOAD AND FLOW AT PE-14

J.E. Ayars, R.A. Schoneman, D.A. Kaddumi

OBJECTIVES: Characterize the discharge and salt load from the main drain leaving the Panoche Water and Drainage District.

PROCEDURES: Personnel from the Panoche Water and Drainage District monitor the drain flow and collect water samples monthly at each drainage point in the district. The water samples are analyzed for electrical conductivity, boron and selenium. The results of the analysis along with the flow data are summarized each year by Summers Engineering. The data from the drainage data summary were used in the calculation of flow and load.

RESULTS: The total yearly outflow at PE-14 is given in Table 1 along with the total salt load and average concentration. These data show that the there has been nearly a 14,000 acre-foot reduction in the flow at PE-14 since 1987. This occurred during a period when the water delivery was reduced by approximately 30,000 ac-ft. The reduced water flows are a result of the continuing drought.

Table 1. Total yearly outflow and salt load at PE-14.

Year	Outflow (ac-ft)	Salt Load (tons)	Concentration (tons/ac-ft)
1986	33,257	104,374	3.14
1987	34,724	113,891	3.28
1988	30,144	110,873	3.68
1989	24,875	96,230	3.87
1990	19,835	81,401	4.10

The data show that there has been a 20,000 ton decrease in the yearly salt load from this district, however, because there has also been less water delivered and consequently less runoff, the concentration of the discharge has increased.

The monthly pattern of discharge from PE-14 is given in Figure 1. Both the peak and minimum discharges have been decreasing during the past 4 years. There is still the same cyclic pattern of discharge which corresponds to the increase in irrigation during the spring and summer months. The flow and salt load are given in a bar graph in Figure 2 and the increase in concentration is shown in Figure 3.

FUTURE PLANS: The data will be used to prepare a final report to the California Department of Water Resources and for manuscripts.

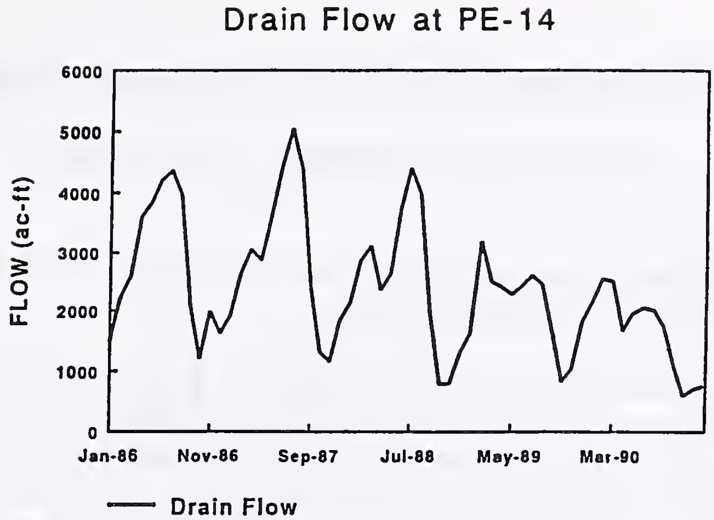

Fig 1 Monthly drain flow PE-14.

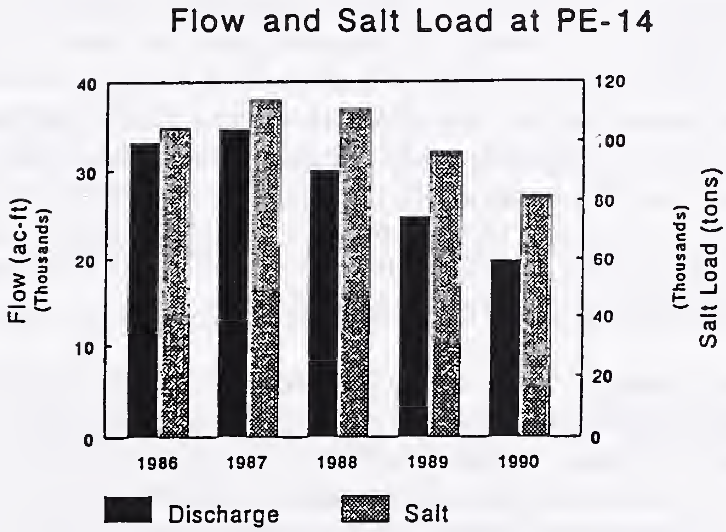

Fig 2. Annual total discharge and salt load from PE-14

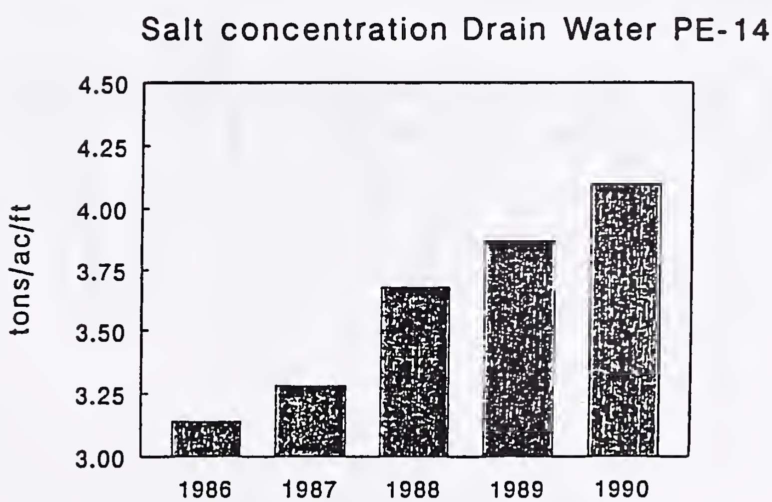

Fig 3. Average annual salt noncentration of discharge from PE-14

LOAD FLOW STUDIES II: BORON AND SELENIUM LOAD AT PE-14

J.E. Ayars, R.A. Schoneman, D.A. Kaddumi

OBJECTIVES: Characterize the discharge and boron and selenium load from the main drain leaving the Panoche Water and Drainage District.

PROCEDURES: Personnel from the Panoche Water and Drainage District monitor the drain flow and collect water samples monthly at each drainage point in the district. The water samples are analyzed for electrical conductivity, boron and selenium. The results of the analysis along with the flow data are summarized each year by Summers Engineering. The data from the drainage summary were used in the calculation of flow and load.

RESULTS: The monthly discharge at PE-14 has been plotted along with the loads for Se and B in Figures 1 and 2. Even with the reduced flows, the total Se load has remained fairly constant. The cyclic pattern of the load corresponds to increases in the flow (Figure 1). The boron concentration in the drain flow has shown a steady increase during the last two years (data not shown). This has resulted in the boron load remaining fairly constant even though the total flow has decreased (Figure 2). The same patterns are occurring with the salt load as were demonstrated by the boron. The EC has increased steadily over the past 2 years while the flow has decreased (data not shown). The salt load has decreased some but not in proportion to the reduction in flow.

The increased concentration of boron and EC coupled with the reduced delivery suggest that there is a larger proportion of subsurface drainage flow in the outflow at PE-14 in recent years than previously. Without data for the flow at the drainage weirs it is not possible to quantify the actual subsurface drainage contribution. With less surface water available there is probably more recirculation of surface runoff (tailwater) and thus less water for dilution. This implies that there has been a gradual increase in irrigation efficiency on a district basis during the past several years.

FUTURE PLANS: These results will be used in the final report to the California Department of Water Resources and in manuscripts.

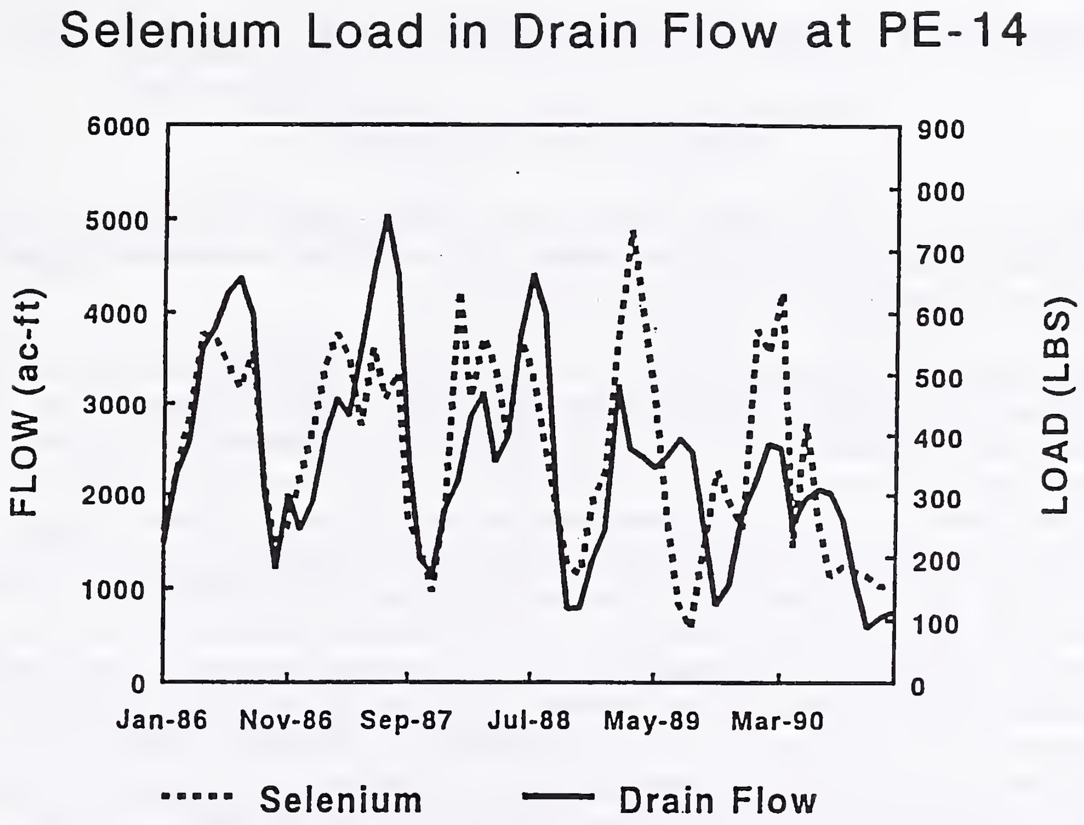

Fig 1.Monthly discharge and selenium load in the drain flow from PE-14

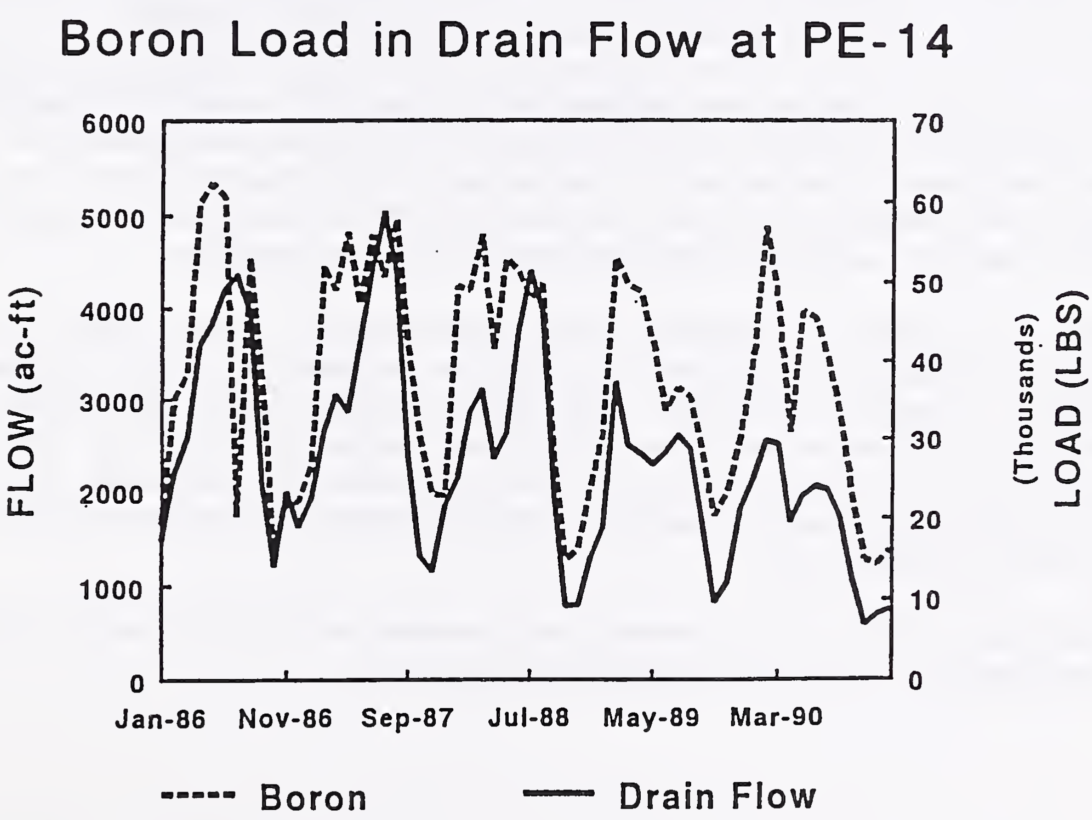

Fig 2. Monthly discharge and boron load in the drain flow from PE-14

SOIL BORON AND SELENIUM REMOVAL BY THREE PLANT SPECIES

G.S. Banuelos, G. Cardon, C. Phene, L. Wu,
S. Akohoue, and S. Zambrzuski

OBJECTIVES: Determine if selected plant species tolerate growing conditions in soils that are simultaneously high in boron (B) and selenium (Se), and if they can substantially lower concentrations of naturally occurring B and Se in the soil.

PROCEDURES: High concentrations of B and Se naturally found in the environment may be detrimental to sustainable agriculture in the western United States. Greenhouse pot experiments were conducted to study B and Se uptake in three different plant species. *Brassica juncea* (wild mustard), *festuca arundinacea* (tall fescue), and *Brassica napus* (canola) were grown in 15 l pots containing Panoche soil (fine-loamy, *Thermic Typic Torriorthext*) with naturally occurring concentrations of 3 mg extractable B kg^{-1} soil and 1.17 mg total Se kg^{-1} soil. The plants were grown in a temperature-controlled greenhouse using a 21° C and 18° (day/night) temperature regime with an average irradiance of 850 μmol $m^{-2}S^{-1}$ from cool white fluorescent lamps for 12 h. 0.1 strength Hoagland nutrient solution No. 2 without B were added weekly to each pot. Trays were placed under each pot to collect any leachate. The experimental design structure was randomized complete block with three treatments, three blocks, and (totalling 18 pots per treatment) six pots per treatment in each block. Controls in each block were pots containing soil and no plants. Pots were irrigated daily based on water loss by weight of each respective treatment throughout the growing season. Any leachate collected was analyzed for B and Se and reapplied to soil. Ninety days after transplanting, wild mustard and canola were harvested, while tall fescue was clipped five cm above the soil surface. Plants were separated into stems, leaves and roots, and soil samples were collected (designated as final harvest I). Five days later, two-week old wild mustard seedlings were replanted into the same soils in which was mustard was previously grown. Seventy d later tall fescue and the replanted wild mustard were harvested (designated as final harvest II). Samples were taken as described above. Plant and soil samples were analyzed for B spectrophotometrically with the Azomethine method and Se by atomic absorption spectrophotometry with continuous hydride generation.

RESULTS: The highest concentrations of tissue B were recovered in shoots of wild mustard and canola at final harvest I, while roots from tall fescue contained the highest concentrations of B (Table 1). Tissue Se concentrations were similar in all plant species. Extractable soil B concentrations at harvest time were lowered by all three species (Table 2). Water extractable Se and total Se were lower in soils from wild mustard and canola than tall fescue. The planting of wild mustard, canola, or tall fescue can substantially reduce water-extractable B and Se, and total Se in the soil.

FUTURE PLANS: Field study is currently being conducted on B and Se-laden soils with the same plant species. A manuscript has already been submitted.

Table 1. Mean concentrations of boron and selenium in shoots and roots from tested plant species at final harvest I and II.*

Species	Shoots B (mg.kg^{-1})	Shoots Se (mg.kg^{-1})	Roots B (mg.kg^{-1})	Roots Se (mg.kg^{-1})
Final Harvest I				
B.juncea	170.00(3.93)†a‡	1.21(0.06)a	17.33(1.76)a	0.82(0.23)a
B.napus§	186.33(3.43)a	1.31(0.07)a	30.00(2.56)b	0.37(0.10)a
F.arundinacea¶	91.67(6.05)b	1.28(0.13)a	--	--
Final Harvest II				
B.juncea	150.42(14.36)a	1.01(0.07)a	25.30(2.24)a	0.23(0.03)a
B.napus§	--	--	--	--
F.arundinacea¶	55.75(6.12)b	0.94(0.06)a	42.57(3.23)b	0.97(0.04)b

* Concentrations are presented as means of six replications.

† Values within parenthesis represent standard error of mean.

‡ Means separation in columns obtained by Tukey's range test. The same letters represent no significant differences between species at the ($P<0$ .05) level.

§ Species was not replanted for final harvest II.

¶ Species was only clipped at final harvest I and allowed to regrow.

Table 2. Total amount of extractable boron and selenium and total selenium removed from the soil by tested species at harvest.*

Species	Total Se removed (mg Se kg^{-1}) Final I	Final II
Control†	0.16(0.25)‡a§	0.27(0.014)a
B. juncea	0.28(0.04)b	0.48(0.034)b
B. napus	0.36(0.026)b	NA
F. arundinacea	NA	0.45(0.025)b

Species	Extractable Se removed (μg Se L^{-1}) Final I	Final II
Control	24.40(0.708)a	29.28(0.829)a
B. juncea	37.58(0.196)b	37.83(0.112)b
B. napus	37.88(0.065)b	NA
F. arundinacea	NA	32.07(1.963)a

Species	Extractable B removed (mg B kg^{-1}) Final I	Final II
Control	0.27(0.105)a	0.62(0.073)a
B. juncea	0.97(0.093)b	1.12(0.113)b
B. napus	0.98(0.076)b	NA
F. arundinacea	NA	1.11(0.064)b

* Initial extractable B was 3.0 mag B L^{-1} and total Se was 1.17 mg Se kg^{-1}.
† Without plants.
‡ Concentrations are presented as means of six replications. Values within parenthesis represent standard error of mean.
§ Mean separation in columns obtained by Tukey's range test. The same letters represent no significant difference between species at the P=0.05 level.
NA - Not applicable.

REMEDIATING BORON AND SELENIUM LADEN SOILS BY FOUR PLANT SPECIES

G.S. Banuelos, G. Cardon, B. Mackey, L. Wu
P. Beuselinck, S. Zambrzuski and S. Akohoue

<u>OBJECTIVES</u>: To determine the extent to which selected plant species tolerate and absorb boron (B) and selenium (Se) and contribute to the reduction of soil B and Se levels.

<u>PROCEDURES</u>: A multiple year study is being conducted on Three Way Farms near Los Banos, CA. The field site had been previously planted to ornamental eucalyptus for at least three years prior to the current study. The first year, the treatment design was a completely randomized design with each treatment replicated eight times. There was a total of 36 subplots, each 10 by 10 m in size. Treatments consisted of the following plant species: *Brassica juncea* (wild mustard), *Festuca arundinacae* (tall fescue), *Lotus cornciculatus* (birdsfoot trefoil), and bare plots (no plants)

The second year, the treatment design was a completely randomized design with each treatment replicated three times. There were a total of fifteen plots, each plot was 30 by 30 m. Treatments consisted of the following plant species: wild mustard, tall fescue, birdsfoot trefoil, *hibiscus cannabinis* (kenaf), and bare plots. In both experiments, all species were hand transplanted as three-week old seedlings, except for kenaf (planted by seed). Prior to planting in the spring for both experiments, four separate soil samples were collected within each subplot from the depth intervals of 0-30 and 30-60 cm, and repeated in the same location at harvest. The plots were sprinkler irrigated with California Aqueduct Canal water (Ec < 0.8 dS m^{-1}). Tall fescue and birdsfoot trefoil subplots were hand clipped 60, 85, and 115 days after transplanting, wild mustard 60 days, and kenaf 115 days after planting. After each clipping of harvest, plants were separated into leaves, stalks, and when applicable roots. Plant and soil samples were analyzed for total B and extractable B, respectively, by azomethine and total Se by atomic absorption with continuous hydride-generation.

<u>RESULTS</u>: In experiment 1, there were no significant differences in the accumulation of tissue B or Se among the species (Table 1). High pre-plant soil B did not correlate to high tissue B concentration, although tissue Se was correlated ($r=0.63$) to pre-plant soil Se. Soil B concentration were all lowered from each of the three species, however, species were not different from each other (Table 1). Only soil Se levels from plot supporting wild mustard were reduced at the $P=0.05$ level. In experiment 2, shoot tissue concentrations of B ranged from a low of 78 mg B kg^{-1} DM in tall fescue and reached a high 1200 mg B kg^{-1} DM in kenaf. When considering all of the shoot B data for all species, shoot B was correlated with pre-plant soil B ($r= 0.66$ and $z= 0.46$). Selenium tissue concentration ranged from a low of 0.2 mg Se kg^{-1} DM in birdsfoot trefoil and a high of 1.1 mg Se kg^{-1} DM in wild mustard. Shoot Se data from all species was correlated ($r=0.60$ and $z=0.44$) with pre-plant soil Se level. Soil B reductions were all lowered at the $P=0.001$ level from all species, however, species were not different from one another (Table 1). The reduction of soil Se levels supporting tall fescue, birdsfoot trefoil and kenaf were all different than control plots at the $P=0.05$ level, while wild mustard was different at the $P=0.01$ level (Table 1).

<u>FUTURE PLANS</u>: Repeat planting and evaluate crop rotations on B and Se removed. A manuscript is currently being prepared.

Table 1 Preliminary pre-plant and postharvest concentration of soil extractable boron and total selenium and mean concentrations of tissue boron and selenium in different plant species.

	Species	Depth (cm)	Soil Boron and Selenium Concentrations at				Plant*	
			Pre-plant (mg B kg^{-1})	Postharvest	Pre-plant (mg Se kg^{-1})	Postharvest	B (mg kg^{-1} DM)	Se
Year 1**								
	Control (no plants)							
		0-30	4.9(1.9)	3.7(1.5)	0.79(.10)	0.70(.08)	NA	
		30-60	5.9(1.8)	5.4(1.9)	0.79(.14)	0.69(.07)	NA	
	Wild mustard							
		0-30	3.3(1.5)	0.70(.18)	0.49(.47)	0.05(.04)	175(18)	0.78(.15)
		30-60	6.5(2.6)	3.5(2.2)	0.95(.39)	0.59(.19)		
	Tall fescue							
		0-30	4.5(2.1)	2.7(2.3)	0.64(.31)	0.41(.19)	75(23)	0.28(.17)
		30-60	6.6(1.6)	4.2(1.5)	0.86(.29)	0.72(.20)		
	Birdsfoot trefoil							
		0-30	5.2(1.4)	3.9(1.4)	0.75(.29)	0.59(.15)	131(20)	0.38(.12)
		30-60	6.3(2.2)	3.1(1.9)	0.93(.19)	0.78(.20)		
Year 2***								
	Control (no plants)							
		0-30	6.0(1.7)	5.3(1.1)	0.83(.20)	0.75(.13)	NA	
		30-60	6.8(1.3)	6.0(1.8)	0.79(.14)	0.70(.12)	NA	
	Wild mustard	0-30	5.8(2.0)	3.0(1.2)	0.89(.13)	0.58(.09)	302(29)	1.09(.14)
		30-60	6.8(2.0)	3.2(1.1)	0.91(.17)	0.70(.13)		
	Birdsfoot trefoil							
		0-30	5.4(1.4)	3.8(.89)	0.76(.14)	0.56(.08)	145(18)	0.75(.12)
		30-60	5.5(2.4)	4.1(1.4)	1.02(.11)	0.92(.14)		
	Tall fescue	0-30	3.9(1.9)	2.5(1.2)	1.16(.23)	0.89(.13)	101(20)	0.63(.10)
		30-60	4.9(1.1)	3.0(1.0)	0.85(.16)	0.69(.09)		
	Kenaf	0-30	6.9(1.3)	4.8(1.5)	0.87(.21)	0.71(.14)	985(39)	0.76(.20)
		30-60	6.4(2.5)	3.9(1.9)	0.98(.15)	0.75(.16)		

* Mean values from shoot tissue concentrations in cut 1.

** Mean value from nine replications with standard deviation in parenthesis.

*** Mean value from four replications with standard deviation in parenthesis.

NA Not applicable for this treatment.

EVALUATION OF *ATRIPLEX* SPECIES IRRIGATED WITH SALINE DRAINAGE WATER

C. Watson and G. Banuelos

<u>OBJECTIVES</u>: To evaluate the accumulation of selenium, boron and other trace elements in native and non-native species of *Atriplex* irrigated with on-site agricultural effluent.

<u>PROCEDURES</u>: Field trials were conducted on the West side of the San Joaquin Valley. At this field site (Westlake Farms), fifteen *Atriplex* species were planted into tile-drained test plots with a total area of 2.4 h. Table 1 lists the plants that were tested and the origin and life cycle duration of each species. There were differences in total planted areas for each species due to limitation in the availability of a source of seeds or plant cuttings. Facilities were in place to pump surface water from the Kings River Irrigation District (non-saline water) and agricultural effluent collected from Westlake Farms. Plants were initially sprinkled with non-saline water during plant establishment (Ec < 0.8 dS m^{-1}) and then flood irrigated in level basins with drainage water (Ec > 18 dS m^{-1}) thereafter. Species were harvested four times beginning in August, 1989 using standard farm equipment, dried in wind rows and baled. Representative bales of selected species were sampled using a modified core sampler tube and replicate samples were analyzed for Se by atomic absorption with continuous hydride generation, for B by Azomethine method, and other elements by atomic absorption. Soil samples were collected to a depth of 90 cm prior to planting and after the final harvest. Chemical analyses of pH, electrical conductivity (Ec), Na and sodium adsorption ratio (SAR) were from saturated paste extracts using standard techniques (US Salinity Laboratory).

<u>RESULTS</u>: Seeding trials of native *Atriplex* species at several sites in the San Joaquin Valley have been generally unsuccessful for some of the same reasons that cause failure in establishment of conventional crops; inappropriate seed depth placement, soil surface crusting, damping off and weed competition. The annuals *A. holocarpa*, *A. spongiosa*, *A. lindleyi*, and *A. velutinella* are generally more herbaceous and less woody than the perennial shrubby species. The desirable agronomic attribute among the perennial species is the ability to produce adventitious roots along stems or branches. This attribute could promote rapid regrowth recovery after cutting. Several of the native species were affected by rootrot pathogens during the hot summer months. Record low temperatures affected the *A. barclayana* most strongly. Mean values of ash levels were generally higher in *A. nummularia*, *A. deserticola* and *A. undulata*. Crude protein levels ranged from 7-13% (determined by A & L Laboratory, Modesto, CA); data not shown. Lignin levels were overall higher in Atriplex than in alfalfa or wheat straw. Selenium and boron levels of these plants are presently being determined for all harvests. Preliminary data shows B and Se levels increasing with each subsequent harvest (Table 2). The extent that Se and B levels will increase in soils after multiple irrigations with drainage water is presently being determined. If harvested plants contain elevated levels of B, Se or other constituents, this limits the amount of plant material that can be incorporated into an animal feed ration.

<u>FUTURE PLANS</u>: Finish analyses of Se, B, and other ions. A manuscript will be under preparation.

Table 1. *Atriplex* species tested including origin, life cycle duration and total area planted at Westlake Farms, San Joaquin Valley, California.

Species	Origin	Duration	Total planted area ———ha———
A. barclayana	North America	Perennial	0.18
A. lentiformis	North America	Perennial	0.08
A. polycarpa	North America	Perennial	0.37
A. cannescens	North America	Perennial	0.39
A. undulata	South America	Perennial	0.29
A. deserticola	South America	Perennial	0.39
A. vestita	South Africa	Perennial	0.09
A. halimus	Israel	Perennial	0.04
A. nummularia	Australia	Perennial	0.08
A. cinerea	Australia	Perennial	0.05
A. paludosa	Australia	Perennial	0.02
A. velutinella	Australia	Annual	0.04
A. holocarpa	Australia	Annual	0.01
A. spongiosa	Australia	Annual	0.01
A. lindleyi	Australia	Annual	0.01

Table 2. Preliminary data on the selenium and boron concentrations in selected *Atriplex* species irrigated with saline drainage water*

Atriplex species	Cut 2		Cut 3		Cut 4**	
	Se	B	Se	B	Se	B
	(mg kg^{-1} DM)		(mg kg^{-1} DM)		(mg kg^{-1} DM)	
A. cinerea	.526(.18)	103(13)	.382(.05)	103(13)	–	–
A. canescens	.331(.09)	89(13)	.266(.04)	139(13)	–	–
A. deserticola	.410(.06)	72(2)	.799(.05)	107(9)	–	–
A. halimus	.470(.10)	85(4)	.331(.03)	81(9)	–	–
A. nummularia	.360(.02)	105(8)	.545(.05)	133(6)	–	–
A. polycarpa	.470(.04)	86(23)	.377(.07)	126(2)	–	–
A. sagittifolia	.303(.05)	107(16)	.388(.08)	132(38)	–	–

* Values presented represent the means from at least three replications and standard deviation.

** Analyses are presently being performed.

MICRO-IRRIGATION OF ALMONDS: OPERATIONAL PROCEDURES FOR 1991

H.I. Nightingale, R.B. Hutmacher, C.J. Phene, F.Dale,
D. Peters, S.S. Vail, D.E. Rolston, P. Brown, and J.W. Biggar

OBJECTIVES: (1) To determine the water requirement and physiological responses of developing almond trees using a line-source trickle irrigation system; (2) to evaluate plant responses to differences in wetted area generated by trickle and microspray irrigation systems and resulting soil salinity profiles; and (3) to determine potential for plant accumulation of boron or other potentially toxic constituents and injury under long-term use of saline irrigation water.

PROCEDURES: Experimental Design: All trees are in a Panoche Clay loam soil at the West Side Field Station of the University of California in a 6.1 m by 6.1 m square pattern which was planted in 1980. The 19 treatment combinations shown in the table below were randomized within each block in the 3.4 ha orchard. Expt. #1 involves the Butte (coded "B" in table below) cultivar with 12 treatment combinations in 7 blocks with 7 trees per block. Part "A" of expt. #1 is an evaluation of crop response to a range of applied water (using five water application levels, described as fractions of ET (0.6, 0.8, 1.0, 1.2, 1.4 times estimated crop evapotranspiration (ET_c)). In years prior to 1990, this study

Table 1. Summary of treatments, trickle irrigated almond experiment at the West Side Field Station.

Expt. No.	Irrigation level code	Water quality code	Irrigation system code	Treatment plot code	Water applied by treatment (% ET_c)
1	1	S	T	1SBT	120
	1	N	T	1NBT	60
	2	S	T	2SBT	120
	2	N	T	2NBT	80
	3	S	T	3SBT	100
	3	N	T	3NBT	100
	3	S	M	3SBM	140
	3	N	M	3NBM	140
	4	S	T	4SBT	120
	4	N	T	4NBT	120
	5	S	T	5SBT	70
	5	N	T	5NBT	140
2	1	N	T	1NRT	60
	2	N	T	2NRT	80
	3	N	T	3NRT	100
	3	S	T	3SRT	100
	3	N	M	3NRM	140
	4	N	T	4NRT	120
	5	N	T	5NRT	140

also consisted of an evaluation of drip-irrigated almond responses to two water qualities (saline (S) local groundwater versus non-saline (NS) irrigation district surface water). Water qualities are more fully described in the report which follows this one. Due to the continuing drought and limited water supplies at the West Side Field Station, it was not possible to continue the water quality comparison begun in 1988, and the saline groundwater remained the principal water source to the field for over 70% of the applied water. Part "B" of Expt. #1 is an irrigation system wetted area comparison study using microspray (M) irrigation to increase the wetted area as compared with the in-line trickle (T) emitter systems used in the remainder of the field. Experiment #2 utilizes the Ruby (coded "R") cultivar with 7 treatment combinations in 6 blocks with 7 trees per block. Part "A" of Expt. #2 compares the response of this cultivar to 5 different irrigation levels and one water quality, with the exception of a saline water quality comparison at the middle ET level. Part "B" of expt. #2 was a microspray versus line-source drip comparison at one irrigation level in the Ruby cultivar.

The line sources trickle system for each row of 7 trees is Netafim in-line emitters (7.57 L h^{-1}) with a 81 cm spacing in sets of 6 emitters per tree centered on each tree. On each side of the tree, this spacing results in one emitter 41 cm away from the center of the tree, the second at 122 cm, and the third at 203 cm. The microspray system consists of Bowsmith Fan-jets (270 degrees spray at 23.1 L h^{-1}) with two sprays per tree and approximately a 4.5 to 5.5 m wetted diameter. Changes in soil water content were determined with neutron probe methods using access tubes on one side of selected trees.

Samples of applied water were collected weekly for determination of average EC and major cations and anions. The mean EC for the groundwater was 1.71 dS m^{-1}, while the non-saline surface water (used primarily in the spring) averaged 0.52 dS m^{-1}.

Water applications and rainfall during the principal irrigation season (March through September) are shown in Table 2.

Table 2. Cumulative applied water during the period from calendar day 95 through day 284 in saline and nonsaline drip irrigated almond treatments at the West Side Field Station in 1991.

Saline Irrigation Treatment Codes	Applied irrigation Water (m^3 $tree^{-1}$) [a]	Nonsaline Irrigation Treatment Codes	Applied Irrigation Water (m^3 $tree^{-1}$) [a]
1ST	31.4	1NT	17.1
2ST	31.7	2NT	22.3
3ST	27.1	3NT	27.2
3SM	36.7	3NM	36.7
4ST	32.2	4NT	32.2
5ST	20.5	5NT	37.2

[a] rainfall during 1991 at the West Side Field Station was:

14 mm in January	1 mm in April	3 mm in November
33 mm in February	2 mm in September	28 mm in December
122 mm in March	5 mm in October	

MICRO-IRRIGATION OF ALMONDS: BORON UPTAKE AND SALINITY INTERACTIONS

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J.W. Biggar, A. Bravo

OBJECTIVES: (1) To determine the potential for plant accumulation of boron or other potentially toxic constituents and injury under long-term use of saline irrigation water in drip irrigated almonds.

PROCEDURES: Experimental Design: All trees are in a Panoche Clay loam soil at the West Side Field Station of the University of California in a 6.1 m by 6.1 m square pattern which was planted in 1980. The 19 treatment combinations are described in the previous report "Micro-irrigation of almonds: Operational Procedures" elsewhere in this report). Expt. #1 involves the Butte ("B" in table below) cultivar with 12 treatment combinations in 7 blocks with 7 trees per block. Part "A" of expt. #1 is an evaluation of crop response to a range of applied water (using five water application levels, described as fractions of ET (0.6, 0.8, 1.0, 1.2, 1.4 times estimated crop evapotranspiration (ET_c)).

Part "B" of Expt. #1 is an irrigation system wetted area comparison study using microspray (M) irrigation to increase the wetted area as compared with the in-line trickle (T) emitter systems used in the remainder of the field. Experiment #2 utilizes the Ruby (coded "R") cultivar with 7 treatment combinations in 6 blocks with 7 trees per block. Part "A" of Expt. #2 compares the response of this cultivar to 5 different irrigation levels and one water quality, with the exception of a saline water quality comparison at the middle ET level. Part "B" of expt. #2 was a microspray versus line-source drip comparison at one irrigation level in the Ruby cultivar.

The line sources trickle system was described in the previous report "Microirrigation of almonds: Operational Procedures". This portion of the experiment has two basic parts: (1) a continuing sampling of plant tissue which was initiated in 1984 to monitor long-term changes in plant nutrient status and potential plant toxicity problems in foliar, woody, and fruit tissues; and (2) a cooperative study with Dr. P. Brown of the UC Davis Pomology Department in which tissue boron accumulation and distribution within the plant are being investigated during the 1989 through 1992 seasons. Part of this study is funded through the Salinity/Drainage Task Force administered through the University of California. The UC Davis part of the investigation includes application and monitoring of the isotope ^{10}B in the soil and trees as a function of time, and an investigation of the ameliorative effects of Ca on B accumulation and toxicity.

Spur branch leaf samples were collected from a minimum of three trees in each of three to five field replicates at monthly intervals throughout the experiment. Bark, spur branches, and other woody tissue were collected twice per year, while nut meat subsamples were collected from the field harvest each year.

RESULTS: Tissue samples were collected and analyses partially completed for B, Na, and Cl. Visual foliar damage symptoms were assessed across all treatments, with the worst visual damage consistently occurring in trees which had received saline irrigation water at low leaching fractions during prior seasons. Visual foliar damage was consistently worse in the "Ruby" cultivar, although preliminary results indicate similar leaf and stem B concentrations in leaves of both cultivars. Leaf and stem Cl concentrations analyzed to date indicate consistently higher Cl levels and slightly higher Na levels in saline-irrigated trees of the Ruby cultivar as compared to the Butte cultivar.

In analyses both at WMRL and UCD, it was found that the concentrations of B were consistently highest in fruit (in excess of 200 to 400 mg/kg in late season), with significantly lower B concentrations in leaves (less than 80 to 100 mg/kg) and spur branches (less than 80 mg/kg) in the late season (July - August). Concentrations of B were quite variable across the season in leaf and stem tissue, with gradual increases in leaf B concentrations and slight reductions in stem B concentration during most of the season (April through August) followed by a rapid reduction to less than 30 to 50 mg/kg during the harvest/leaf fall period. In leaf, stem, and fruit tissue, higher tissue B levels prevailed in treatments which received saline irrigation water during seasons prior to 1991.

FUTURE PLANS: Water applications in this experiment will continue during the 1992 season only to allow collection of data on basic tree growth responses, measurement of root distribution and activity as a function of depth and distance from the drip lateral, and to allow continued monitoring of long-term tree responses to accumulated boron, chloride, and other potentially toxic constituents of applied water. UC Davis personnel will conduct evaluations of potential interactions between applied Calcium and resulting B accumulation and toxicity. Sampling of tree tissue and select tree harvests will be concluded during the fall of 1992, at which time the trees will be removed to make way for a new orchard experiment.

MICRO-IRRIGATION OF ALMONDS: GROWTH AND PLANT WATER RELATIONS

H.I. Nightingale, R.B. Hutmacher, C.J. Phene, F.Dale,
S.S. Vail, D.E. Rolston, D. Peters, J.W. Biggar, A. Bravo

OBJECTIVES: (1) To determine the water requirement and physiological responses of developing almond trees using a line-source trickle irrigation system; and (2) to evaluate plant responses to differences in wetted area generated by trickle and microspray irrigation systems and resulting soil salinity profiles.

PROCEDURES: All trees are in a Panoche Clay loam soil at the West Side Field Station of the University of California in a 6.1 m by 6.1 m square pattern which was planted in 1980. The 19 treatment combinations and the line source drip irrigation system are described in the previous report "Micro-irrigation of almonds: Operational Procedures" elsewhere in this report). Tree trunk diameters were measured in late fall of 1990 and 1991 as a general index of tree growth. Scaffold branch diameter data was measured at 6 to 8 week intervals during the season to determine within-season differences in growth responses across treatments.

Leaf water potentials (LWP) were monitored on six separate days during the season using a pressure chamber apparatus. Four fully-illuminated leaves from recently-developed spur branches from each plot in each of three field replicates were placed in plastic bags, excised, and placed in humid containers for transport to the pressure chamber. LWP values were determined within 15 minutes of collection. Subsamples were frozen in liquid N, and osmotic potentials were determined using leaf cutter psychrometers. On six different dates during the season, leaves (in water level treatments T1, T2, T4, T6) from lower canopy spur branches near the main stem were placed in plastic bags and covered with foil in pre-dawn hours. These leaves should represent water potentials of non-transpiring leaves roughly in equilibrium with that in the stem tissue.

RESULTS: There were no significant differences in the Butte tree trunk diameters associated with water quality treatments for any of the 5 irrigation levels (Table 1). The tree trunk diameters of the Butte cultivar were consistently greater than in the Ruby cultivar across all irrigation treatments. There was no significant influence of microspray irrigation treatments on tree trunk diameter. Tree trunk diameters represent a cumulative response to all prior treatment, and therefore are not particularly sensitive in identifying responses to current season treatments.

Changes in tree trunk diameter across seasons generally reflected water application levels (Table 1). In trees which had received non-saline ("NS") irrigation water in previous years, increases in tree trunk diameter were roughly proportional to applied water. In the Butte cultivar trees previously receiving saline irrigation water, the high water application amounts for 1991 in previously low water level trees (water level 1, 2) produced much higher growth rates than in trees with low water application amounts in 1991 (water level 5 in saline-irrigation treatments). Scaffold branch measurements (data not shown) indicated that branch

radial growth ceased 45 to 60 days earlier in the growing season (late June) in low water application treatments than in higher water application treatments (water level 3 or higher).

Afternoon LWP and stomatal conductance measurements were similar to values reported in previous annual reports and will not be presented in this report. LWP measurements were less variable than conductance measurements, and have acceptable resolution to identify differences in plant water status across water level treatments. Preliminary analysis of this year's data did not indicate significantly greater resolution with the "bagged" (non-transpiring) leaf method compared to standard LWP measurements in comparing tree water status across water quality or water level treatments.

As in previous years, the effect of water quality treatments within an irrigation level on leaf turgor potential were relatively small. However, turgor potential of low water application treatments (T1, T2) were significantly less than treatments at water application level 3 or higher. Osmotic potential data, when combined with relative water content values, indicated significant osmotic adjustment occurring in low leaching fraction, previously saline-irrigated treatments (T1, T2). Almond trees in this study have adapted to water deficit conditions through a variety of mechanisms, including small reductions in leaf conductance, osmotic adjustment, reductions in leaf size and number, and shorter duration of leaf retention during the post-harvest period.

<u>FUTURE PLANS</u>: Water applications in this experiment will continue during the 1992 season only to allow collection of data on basic tree growth responses, measurement of root distribution and activity as a function of depth and distance from the drip lateral, and to allow continued monitoring of long-term tree responses to accumulated boron, chloride, and other potentially toxic constituents of applied water. Sampling of tree tissue and select tree harvests will be concluded during the fall of 1992, at which time the trees will be removed to make way for a new orchard experiment.

Table 1. Tree trunk diameter and tree trunk diameter changes from December, 1990 to December, 1991 in drip-irrigated almonds at the West Side Field Station in 1991.

Treatment Codes				Dec. 1991 Tree Trunk Diameter (cm)		Increase In Diam. Since Dec. 1990 [a]	
Water Level	Water Quality	Tree Cultivar	Irrig. System	Mean	Std. Dev.	Mean	Std. Dev.
1	S	B	T	20.8	±1.2	1.8	±.2
2	S	B	T	22.9	1.4	1.9	.1
3	S	B	T	24.4	1.7	1.4	.1
4	S	B	T	26.0	1.6	1.5	.2
5	S	B	T	26.6	1.3	1.1	.1
1	N	B	T	19.8	1.1	0.8	.1
2	N	B	T	21.8	1.1	1.1	.1
3	N	B	T	24.6	1.5	1.3	.2
4	N	B	T	26.1	1.2	1.4	.1
5	N	B	T	27.3	1.8	1.7	.1
1	N	R	T	15.7	0.8	0.5	.1
2	N	R	T	17.1	1.1	0.6	.0
3	N	R	T	18.9	1.2	1.0	.1
4	N	R	T	20.4	1.3	1.2	.1
5	N	R	T	21.4	1.2	1.4	.1
3	S	R	T	18.7	1.2	0.6	.1
3	S	B	M	23.5	1.5	1.6	.2
3	N	B	M	23.5	0.9	1.7	.2
3	N	R	M	18.1	1.3	0.5	.0

[a] Change in tree trunk diameter during period from December, 1990 to December, 1991.
[b] Shelling fraction defined as kernel air dry weight divided by kernel plus hull dry weights.

MICRO-IRRIGATION OF ALMONDS: NUT YIELDS, KERNEL WEIGHTS

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OBJECTIVES: (1) To determine the water requirement and physiological responses of developing almond trees using a line-source trickle irrigation system; (2) to evaluate plant responses to differences in wetted area generated by trickle and microspray irrigation systems and resulting soil salinity profiles; and (3) to determine potential for plant accumulation of boron or other potentially toxic constituents and injury under long-term use of saline irrigation water.

PROCEDURES: Experimental Design: All trees are in a Panoche Clay loam soil at the West Side Field Station of the University of California in a 6.1 m by 6.1 m square pattern which was planted in 1980. The 19 treatment combinations are described in the previous report "Microirrigation of almonds: Operational Procedures" elsewhere in this report). Expt. #1 involves the Butte ("B" in table below) cultivar with 12 treatment combinations in 7 blocks with 7 trees per block. Part "A" of expt. #1 is an evaluation of crop response to a range of applied water (using five water application levels, described as fractions of ET (0.6, 0.8, 1.0, 1.2, 1.4 times estimated crop evapotranspiration (ET_c)). Part "B" of Expt. #1 is an irrigation system wetted area comparison study using microspray (M) irrigation to increase the wetted area as compared with the in-line trickle (T) emitter systems used in the remainder of the field. Experiment #2 utilizes the Ruby (coded "R") cultivar with 7 treatment combinations in 6 blocks with 7 trees per block. Part "A" of Expt. #2 compares the response of this cultivar to 5 different irrigation levels and one water quality, with the exception of a saline water quality comparison at the middle ET level. Part "B" of expt. #2 was a microspray versus line-source drip comparison at one irrigation level in the Ruby cultivar.

The line sources trickle system was described in the previous report "Micro-irrigation of almonds: Operational Procedures". The field was harvested using machine harvest methods. About two weeks after termination of irrigation in late August, each tree was shaken with a mechanical tractor-mounted shaker, and nuts were swept into windrows and picked up with a mechanical conveyor system. A calibrated weighing trailer was used to measure the yield of a five tree block in each plot. A large (3 to 5 kg) subsample was collected from each plot, air dried, and shelled to allow determination of shelling percentage. Average kernel weight was determined from two 100-kernel subsamples within each plot.

RESULTS: Almond nut meat yields showed some significant differences across water level treatments as in previous years, even though some there were some changes in water applications across treatments relative to earlier years of the study. As noted in the previous report describing the irrigation treatment water application amounts, Butte cultivar trees receiving low water applications of saline water in previous years (Water level 1 and 2 treatments) received higher water application rates in 1991 (equivalent to water level 5), and

those previously receiving high amounts received water at lower rates in 1991 in order to evaluate the sensitivity of tree growth and nut yields to short-term changes in applied water.

Although the range of nut yields across treatments in the Butte cultivar was quite small, yields were still generally lowest in the Water level 1 and 2 treatments (Table 1). In the Butte cultivar, apparently, the number of nuts set and fruiting site number was more influenced by conditions during previous years than by within-season changes in water applications. Nut yields also generally increased with increasing water applications in the Ruby cultivar, where water level treatments remained basically unchanged from the 1990 season. In the Butte cultivar, kernel size was more sensitive to short-term changes in applied water in formerly saline-irrigated treatments. Kernel size in the non-saline irrigated Butte and Ruby trees increased with increases in applied water (Table 1). This sensitivity of kernel size to water application amounts is similar to observations in previous years. As in previous years, shelling fraction was highest in low water application treatments.

Across all irrigation water levels, nut meat yields were significantly lower in trees which had received saline irrigation water during prior seasons (Table 1), even though all treatments received the same quality water during the 1991 season. Explanations for this response have not been established at this time. Previous soil analyses in this orchard demonstrated the accumulation of significant quantities of salts and potentially toxic constituents such as boron near the edge of the wetting front within the root zone. These high concentrations may impose a direct osmotic or specific element effect on the almonds. It is also possible that it took a number of years for chloride, sodium, or other constituents to reach a level within the plants where yields were affected. During 1991, trees receiving saline irrigation water prior to the 1991 season exhibited substantial foliar damage (tip necrosis). Significant foliar damage was not observed during prior years in any treatments nor in nonsaline treatments in 1991. Previous cooperative studies with plums by the WMRL and University of California found a cumulative effect of applied saline water which was in part a chloride toxicity response.

<u>FUTURE PLANS</u>: Water applications in this experiment will continue during the 1992 season only to allow collection of data on basic tree growth responses, measurement of root distribution and activity as a function of depth and distance from the drip lateral, and to allow continued monitoring of long-term tree responses to accumulated boron, chloride, and other potentially toxic constituents of applied water. Sampling of tree tissue and select tree harvests will be concluded during the fall of 1992, at which time the trees will be removed to make way for a new orchard experiment.

Table 1. Nut meat yields, average kernel weights, and shelling fraction of drip irrigated almonds at the West Side Field Station in 1991. Mean and standard deviations (std. dev.) are shown for nut meat yields and kernel weight.

Treatment Codes				Nut Meat Yield (kg ha^{-1})		Average Kernel Weight (mg)		Shelling Fraction [a]
Water Level	Wate Quality	Tree Cultivar	Irrig. System	Mean	Std. Dev.	Mean	Std. Dev.	Mean
1	S	B	T	1261	±178	916	±62	.24
2	S	B	T	1233	122	932	37	.24
3	S	B	T	1398	151	906	65	.22
4	S	B	T	1397	129	890	58	.21
5	S	B	T	1416	258	868	66	.19
1	N	B	T	1596	128	809	19	.24
2	N	B	T	1693	140	852	47	.22
3	N	B	T	1744	220	918	22	.23
4	N	B	T	1931	357	929	72	.23
5	N	B	T	1776	466	957	54	.22
1	N	R	T	1376	220	913	31	.21
2	N	R	T	1528	167	957	47	.20
3	N	R	T	1592	183	1003	61	.17
4	N	R	T	1716	282	1070	43	.20
5	N	R	T	1712	535	1090	75	.17
3	S	R	T	1675	244	961	36	.21
3	S	B	M	900	194	905	25	.21
3	N	B	M	1249	216	968	20	.22
3	N	R	M	1476	198	955	41	.20

[a] Shelling fraction defined as kernel air dry weight divided by kernel plus hull dry weights.

SUBSURFACE DRIP IRRIGATION OF COTTON: OPERATIONAL PROCEDURES

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OBJECTIVES: The overall objectives of this project are to evaluate the responses of three types of cotton grown under subsurface drip irrigation and a narrow-row (76 cm row spacing) production system. Crop water requirements, use of stored soil water, root distribution and density, and specific crop growth, plant water status, and gas exchange responses to irrigation ranging from mild to moderate deficit irrigation in a clay loam soil will be determined in this study.

PROCEDURES: Cotton was grown during 1991 in Panoche clay loam field plots (Fld 40, 54 plots) at the University of California West Side Field Station (WSFS) at Five Points, CA. The "old cotton plots" (WSFS Fld. 40;54 plots; Cotton Projects 1979-1981, 1982-1983, 1985-1987 -- see various Annual Reports and publications) were modified for 1991. During the winter the field was bedded in 76 cm beds and drip irrigation laterals were shanked about 45 cm deep in alternate furrows. The dripline (DL) installed was Rootguard in-line emitters with a nominal flow rate of 4 l/hr and a spacing of 0.9 m.

Retrofit construction began mid-April. Existing PVC mainlines and submain tees were located and exposed. Trenches were excavated inside of the existing mainlines and new plot submains were connected to the mainlines. Also, at the ends of each plot, flushout manifolds were installed. Additional modifications were new sand-media filters, screen filter, updated flow-sensing proportioning pump, and new 18-section meter/valve headwork manifold.

Six subsurface drip irrigation treatments (Table 1) were imposed on three cotton varieties (GC-510, Pima, and Columnar). In addition, each plot was split by PIX versus no-PIX treatments. The treatments were arranged in a randomized split-split plot design and were replicated three times. Each plot was about 27 m long and contained 10 beds. In March 140 mm of preplant sprinkler irrigation was applied. Rainfall was approximately 137 mm in the 30 days prior to planting. Cotton was planted April 8 and emergence was completed by April 20. The cotton was hand-thinned on May 15 to a final population of approximately 110,000 plants/ha. Subsurface drip irrigation (SSD) began on June 3, and for several days all treatments received approximately the same amount of water. Reference evapotranspiration (ETr) from a large weighing grass lysimeter located in adjacent field and a crop coefficient (Kc) determined in 1980 and 1981 from this exact site were used for irrigation scheduling. The calculated ET_c (ETr x Kc) was multiplied by appropriate percentages (Table 1) to determine irrigation amounts. Fertilizer was injected at the headworks with flow- sensing proportioning pumps and applied with the irrigation water through the SSD system. Fertilizer application is shown in Table 2. Soil water content was measured from July 2 to October 16 by neutron probe in access tubes installed in selected plots. Also, gravimetric water content was determined early in the season to supplement the neutron probe measurements. The plant growth regulator, PIX, was applied on July 9. Irrigation was terminated on September 3. Cotton was defoliated on September 28 and

October 11. Cotton was harvested with a single-row spindle picker from one row in each subplot on October 21, 1991.

RESULTS: Total water applied is shown in Table 3. By scheduling irrigation water as described, the in-season SSD irrigation water applied (averaged across varieties) was 419, 377, 332, 316, 351, and 274 mm for treatments 1-6, respectively.

FUTURE PLANS: The experiment will be repeated in 1992.

Table 1. Subsurface drip irrigation treatments as percentage of ET_c for cotton (GC-510, Pima, and Columnar) during 1991.

Irrigation Treatment		ET_c Percentage by Dates			
Number	Name	06/03 to 06/23	06/24 to 07/04	07/05 to 07/31	08/01 to 09/03
1	NS	100	100	100	100
2	NS/D80	100	100	100	80
3	NS/D60	100	100	100	60
4	NS/D80/D60	100	100	80	60
5	D80	100	80	80	80
6	D60	100	60	60	60

Table 2. Amount of fertilizer N,P, and K applied to all treatments in 1991.

Fertilizer Type	Pump No. ( ) and Dates	N	P	K
		kg/ha		
N (as Calcium Ammonium-Nitrate)	(1) 06/27-07/23	171	-	-
P (as H_3PO_4)	(2) 06/27-09/03	-	83	-
K and N (as KNO_3)	(1) 07/24-08/30	41	-	111
Total		212	83	111

Table 3. Average water application for three cotton varieties (GC-510, Pima, and Columnar in 1991.

	Water Applied			
Trt. #	Preplant Sprinkler	Rain	SSD Irrigation	Total
	---------------------------mm---------------------------			
1	140	137	419	696
2	140	137	377	654
3	140	137	332	609
4	140	137	316	593
5	140	137	351	628
6	140	137	274	551

SUBSURFACE DRIP IRRIGATION OF COTTON: APPLIED WATER, SOIL WATER USE, EVAPOTRANSPIRATION

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OBJECTIVES: The overall objectives of this project are to evaluate the responses of three types of cotton grown under subsurface drip irrigation and a narrow-row (76 cm row spacing) production system. Crop water requirements, use of stored soil water, root distribution and density, and specific crop growth, plant water status, and gas exchange responses to irrigation ranging from mild to moderate deficit irrigation in a clay loam soil will be determined in this study.

PROCEDURES: Cotton was grown during 1991 in a Panoche clay loam soil at the University of California West Side Field Station. Row spacing was 76 cm and the drip irrigation laterals were shanked in about 45 cm deep in alternate furrows, centered in the furrows. Details of the drip irrigation system, its operation and application amounts, and methods of determining grass reference evapotranspiration (ET_0) and crop coefficients are given in this volume in the report "Subsurface drip irrigation of cotton: Operational procedures". Six subsurface drip irrigation treatments were evaluated, with the treatments representing six different combinations of percentages of crop ET applied during specific portions of the growing season, as described in the "Operational Procedures" report on this project.

The responses of three types of cotton were evaluated within each of the six irrigation treatments: (1) a commercial narrow-row cotton (GC-510); (2) a columnar-type cotton out of the University of California cotton program; and (3) a "Pima" type (Pima S6). Rainfall, sprinkler applications for germination, and water application amounts (determined based on grass reference ET and a locally-derived crop coefficient) are described in the report "Subsurface drip irrigation of cotton: Operational Procedures" in this volume. Gravimetric water content samples were collected just after planting in early April for the initial water content evaluation. Access tubes (3.1 m length) were installed during June for determination of water content during the season by neutron attenuation. Crop evapotranspiration was calculated as applied water plus rainfall plus soil water depletion, assuming negligible deep percolation.

RESULTS: The crop coefficient used in this study (derived from 1980, 1981, 1987 data reported elsewhere) resulted in considerable use of stored soil water even in the treatments designated as 100% of the crop coefficient times grass reference ET. Stored soil water in the upper 2 m of the soil profile was relatively high in all plots due to unusually high rainfall and sprinkler-applied pre-plant irrigation during the two months prior to planting. Soil water depletion occurred during both the mid- and late-season in all treatments across all three types of cotton, indicating that the crop coefficient results in deficit irrigation during much of the season. Water applied with the drip system ranged from 270 to 422 mm across

treatments (Figs. 1 to 3), while net use of stored soil water during the period from day 166 to 249 ranged from 209 to 417 mm. Extensive, deep development of the root systems and high soil water holding capacity of the clay loam soil at the study site allowed considerable quantities of stored soil water to be used in all plots in this study (Figs. 1 to 3). This resulted in ET_c ranging from a low of 538 mm in treatment T4 (Pima) to a high of 749 mm in treatment T3 of the columnar cotton. In general, ET_c of the Pima type cotton was lower than the Acala types (GC510, Columnar) due to lower soil water depletion.

FUTURE PLANS: This experiment will be repeated in its entirety during the 1992 and 1993 growing seasons.

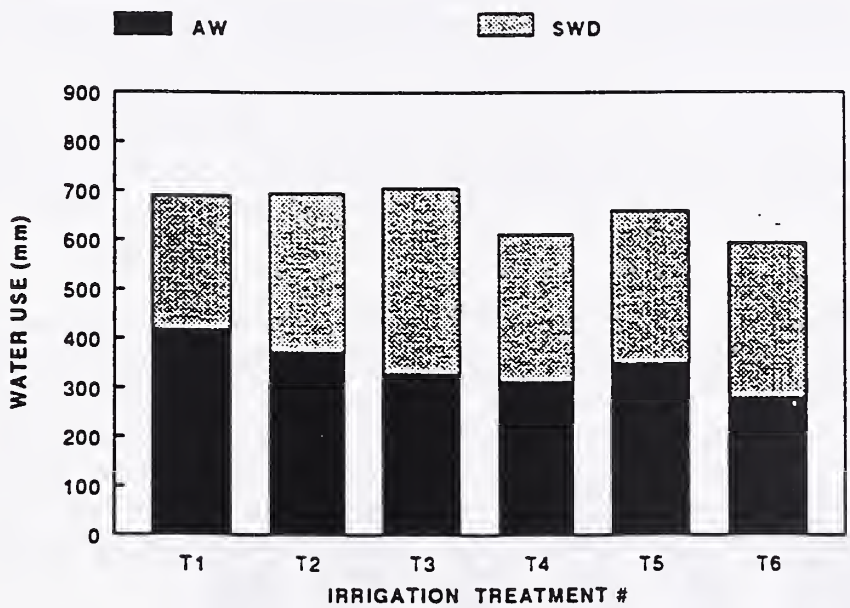


Figure 1. Soil water depletion (SWD) in the upper 3.1 m of the soil profile between calendar days 108 and 289, drip-applied water (AW) between days 166 and 249, and calculated crop evapotranspiration (ET_c) of GC-510 cotton under subsurface drip irrigation at the West Side Field Station in 1991.

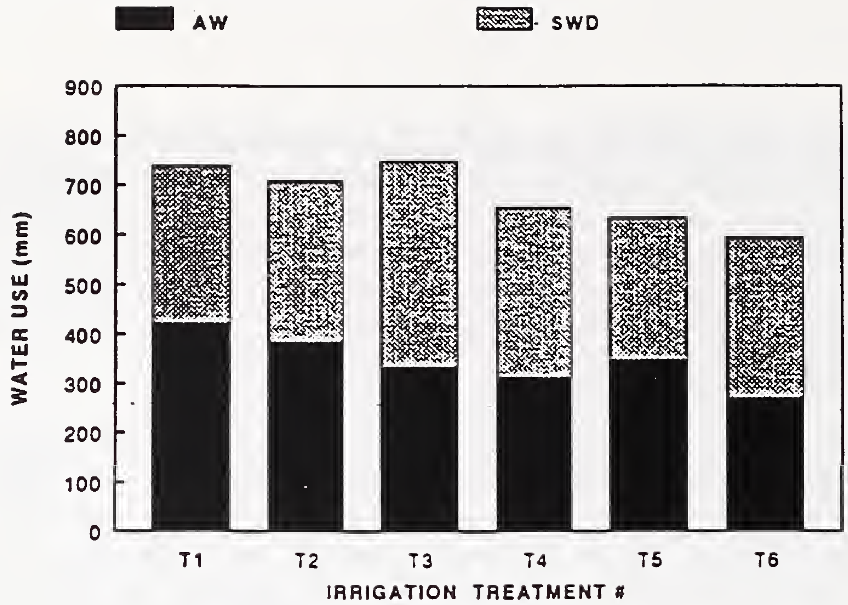


Figure 2. Soil water depletion (SWD) in the upper 3.1 m of the soil profile between calendar days 108 and 289, drip-applied water (AW) between days 166 and 249, and calculated crop evapotranspiration (ET_c) of **Columnar C2** cotton under subsurface drip irrigation at the West Side Field Station in 1991.

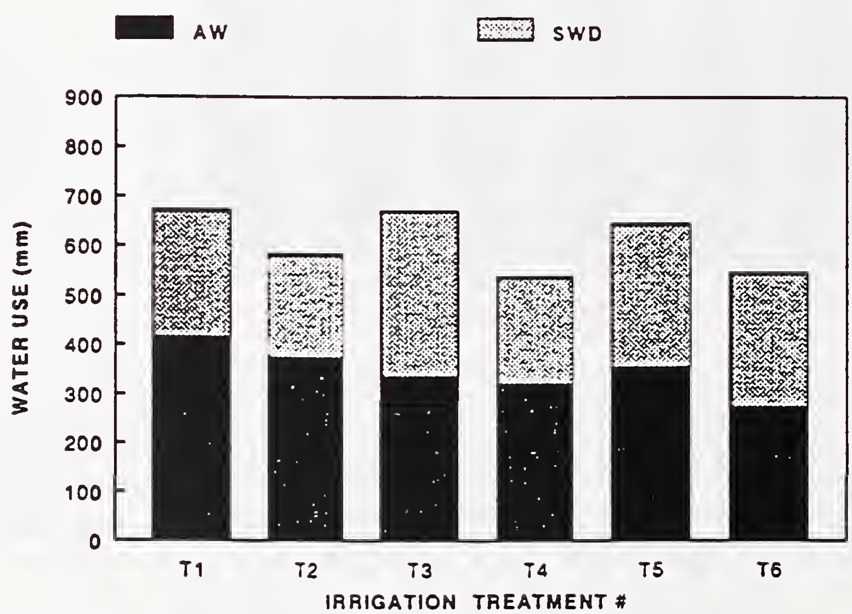


Figure 3. Soil water depletion (SWD) in the upper 3.1 m of the soil profile between calendar days 108 and 289, drip-applied water (AW) between days 166 and 249, and calculated crop evapotranspiration (ET_c) of **Pima** cotton under subsurface drip irrigation at the West Side Field Station in 1991.

SUBSURFACE DRIP IRRIGATION OF COTTON: PLANT WATER RELATIONS

R.B. Hutmacher, C.J. Phene, K.R. Davis, T. Kerby, M. Peters, S.S. Vail, D. Ballard, N. Hudson, A. Bravo, J. Misaki, D. Clark, M. Keeley

OBJECTIVES: The overall objectives of this project are to evaluate the responses of three types of cotton grown under subsurface drip irrigation and a narrow-row (76 cm row spacing) production system. Crop water requirements, use of stored soil water, root distribution and density, and specific crop growth, plant water status, and gas exchange responses to irrigation ranging from mild to moderate deficit irrigation in a clay loam soil will be determined in this study.

PROCEDURES: Cotton was grown during 1991 in a Panoche clay loam soil at the University of California West Side Field Station. Row spacing was 76 cm and the drip irrigation laterals were shanked in about 45 cm deep in alternate furrows, centered in the furrows. Details of the drip irrigation system, its operation and application amounts, and methods of determining grass reference evapotranspiration (ET_0) and crop coefficients are given in this volume in the report "Subsurface drip irrigation of cotton: Operational procedures". Six subsurface drip irrigation treatments were evaluated, with the treatments representing six different combinations of percentages of crop ET applied during specific portions of the growing season, as described in the "Operational Procedures" report on this project.

The responses of three types of cotton were evaluated within each of the six irrigation treatments: (1) a commercial narrow-row cotton (GC-510); (2) a columnar-type cotton out of the University of California cotton program; and (3) a "Pima" type (Pima S6). All three types of cotton were grown at the same planting density and cultural conditions were identical across the three cotton types. Each individual plot was split into 5 rows which were sprayed once per season with the growth regulator "PIX" (Mepiquat chloride), and 5 rows which were not sprayed ("No Pix" plots), with the PIX applied on July 9 at a rate of 0.5 pints per acre.

Early- to mid-afternoon leaf water potentials (LWP) were determined on selected treatments (irrigation and PIX treatments) in all three cotton types (Pima, GC510, Columnar) using a Schollander-type pressure chamber. Three subsamples were evaluated in each of three field replications for each treatment. Fully-illuminated, recently-mature leaves from the fourth or fifth most recent main stem node position were placed in a plastic bag while still on the plant, excised, and stored temporarily in humid, sealed plastic containers, and leaf water potentials were determined within 10 to 15 minutes of collection. Infrared thermometer and psychrometer data for determination of the crop water stress index (CWSI) was also collected in select plots, but will not be discussed here.

RESULTS: Within any measured irrigation treatment, few significant differences in LWP existed between the Columnar and GC510 types. In the early season (calendar days 150 to 180), LWP in the T1 treatment (which received the most applied water) averaged -1.2 to -1.3 MPa in these varieties, declining to about -1.5 MPa in the late season (Fig. 1). In contrast, the LWP in the treatment receiving the least applied water (T6) declined to -1.7 MPa by day 200 and to less than -2.0 MPa by day 215 (Fig. 2). Across all irrigation treatments (T1, T6 shown in Figs. 1, 2 respectively), the Pima type cotton exhibited 0.1 to 0.2 MPa lower LWP than the Acala types. A less extensive root system or differences in plant hydraulic resistance associated with some other plant characteristic may explain this difference. LWP of other irrigation treatments were intermediate between T1 and T6 (data not shown).

FUTURE PLANS: This experiment will be repeated in its entirety during the 1992 and 1993 growing seasons. Similar measurements will be made during each year of the study. These results will provide crop-specific plant water status data to describe specific indexes of plant water deficits that can be associated with favorable or unfavorable yield responses.

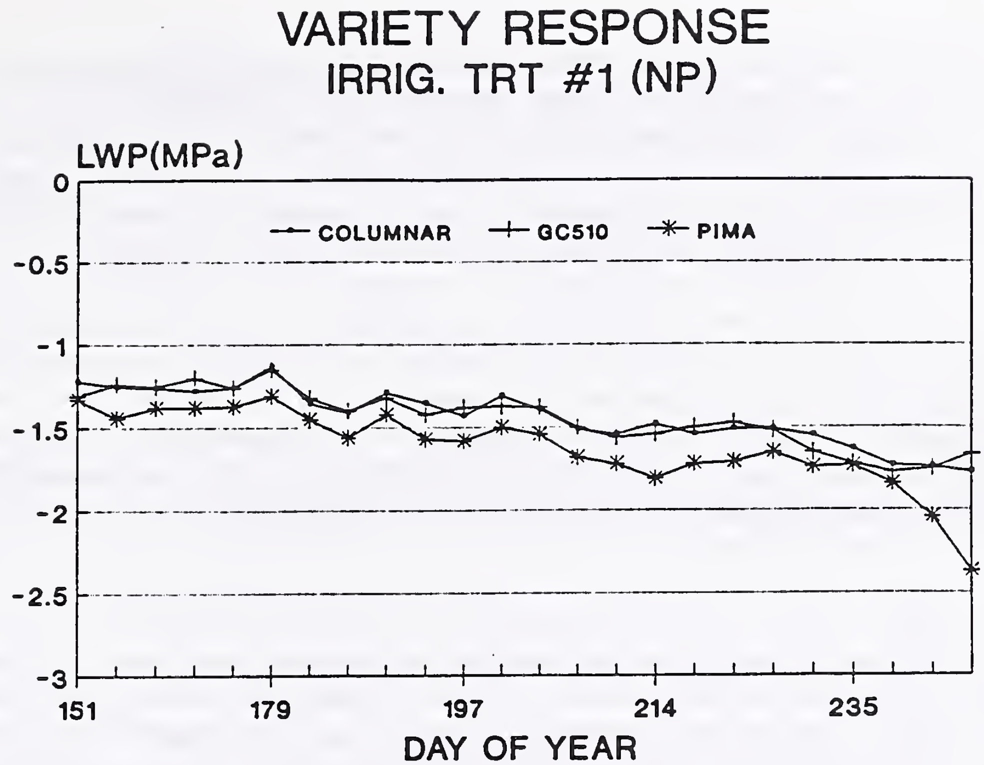


Figure 1. Mid-afternoon leaf water potential (LWP) of fully-illuminated, recent fully-expanded leaves of Columnar, Pima and GC510 types of cotton as a function of day of year in irrigation treatment T1. All data shown is for "no pix" subplots.

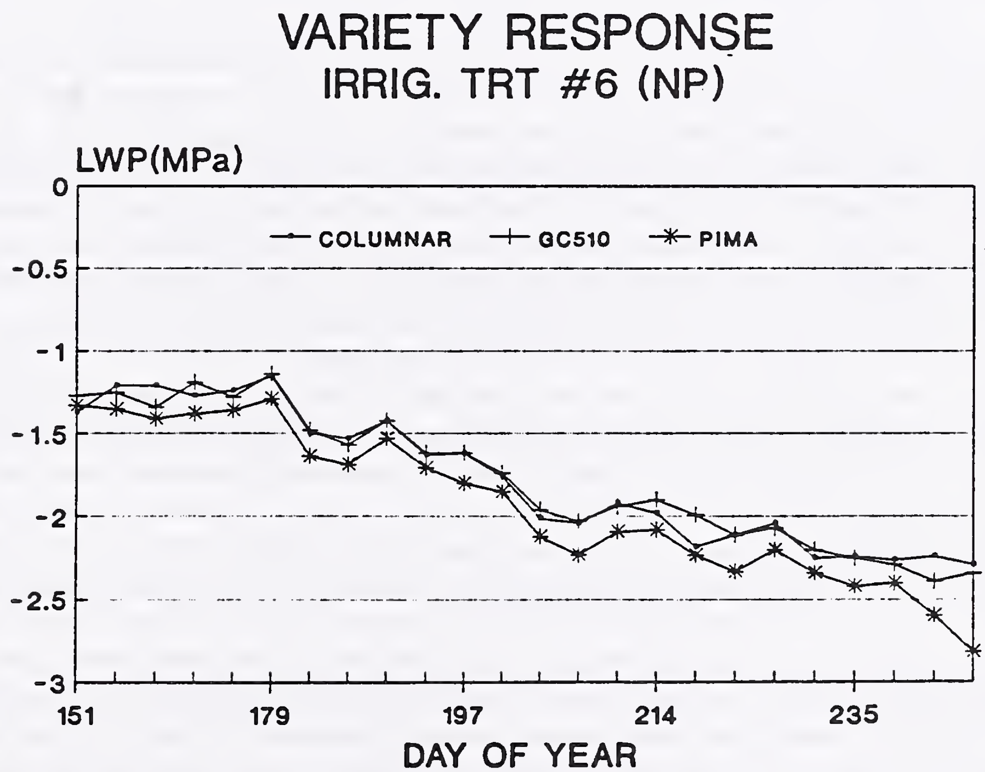


Figure 2. Mid-afternoon leaf water potential (LWP) of fully-illuminated, recent fully-expanded leaves of Columnar, Pima and GC510 types of cotton as a function of day of year in irrigation treatment T6. All data shown is for "no pix" subplots.

SUBSURFACE DRIP IRRIGATION OF COTTON: EFFECTS OF LEAF POSITION AND AGE ON LEAF CONDUCTANCE AND PHOTOSYNTHETIC RATES

R.B. Hutmacher, C.J. Phene, K.R. Davis, T. Kerby, M. Peters, S.S. Vail
D. Ballard, N. Hudson, D. Clark, M. Keeley, A. Bravo

OBJECTIVES: The overall objectives of this project are to evaluate the responses of three types of cotton grown under subsurface drip irrigation and a narrow-row (76 cm row spacing) production system. Crop water requirements, use of stored soil water, root distribution and density, and specific crop growth, plant water status, and gas exchange responses to irrigation ranging from mild to moderate deficit irrigation in a clay loam soil will be determined in this study.

PROCEDURES: Cotton was grown during 1991 in a Panoche clay loam soil at the University of California West Side Field Station. Row spacing was 76 cm and the drip irrigation laterals were shanked in about 45 cm deep in alternate furrows, centered in the furrows. Details of the drip irrigation system, its operation and application amounts, and methods of determining grass reference evapotranspiration (ET_0) and crop coefficients are given in this volume in the report "Subsurface drip irrigation of cotton: Operational procedures". Six subsurface drip irrigation treatments were evaluated, with the treatments representing six different combinations of percentages of crop ET applied during specific portions of the growing season, as described in the "Operational Procedures" report on this project.

The gas exchange responses of three types of cotton were evaluated within two irrigation treatments: (1) a commercial narrow-row cotton (GC-510); (2) a columnar-type cotton out of the University of California cotton program; and (3) a "Pima" type (Pima S6). Gas exchange measurements were limited to treatments T1 and T6. In 1991, all three types of cotton were grown at the same planting density and cultural conditions were identical across the three cotton types. Each individual plot was split into 5 rows which were sprayed once per season with the growth regulator "PIX" (Mepiquat chloride), and 5 rows which were not sprayed ("No Pix" plots), with the PIX applied on July 9 at a rate of 0.5 pints per acre.

Some data from a 1987 and 1988 cotton experiment involving non-stressed drip-irrigated GC510 and Columnar cotton were used for comparison purposes in evaluating leaf age responses. In all years, single leaf photosynthetic rates were determined using a flow-through chamber system with an ADC gas analyzer. A 4.2 cm^2 area was monitored on each sample leaf. Data was collected on GC510, Pima and Columnar types of cotton, however, emphasis was on GC510, a variety widely-grown under narrow-row (76 cm row width) conditions. Only data collected for GC510 will be reported here. Measurements were made on leaves located on the 3rd, 5th, 8th, and 11th most-recent main stem nodes, and on 1st and 2nd position (if present) sympodial leaves arising from the 8th through 11th most-recent nodes. Leaf conductance and transpiration data collected using the leaf chamber were compared with selective measurements made using a steady-state diffusion porometer. In the upper canopy nodes, leaves were fully-illuminated, while lower canopy leaves were monitored under ambient light levels (some measurements specifically made under shaded conditions and some under fully-illuminated conditions). Data on leaves was recorded by node position and average leaf initiation date in order to accurately identify leaf age as well as position.

RESULTS: Influence of position on the plant. Averages single leaf photosynthetic rates across were consistently highest in leaves from the 5th most recent node, and over all sample dates, averaged 17%, 12%, and 22% lower in fully-illuminated 3rd, 8th, and 11th most-recent node leaves, respectively. Leaf conductance values were not tightly linked with photosynthetic rates, with the highest conductance measured in leaves from the 3rd most recent node. Similarly, lower photosynthetic rates in 8th most recent node leaves were not associated with reductions in leaf conductance. To some degree, differences in photosynthetic rates in different leaf positions are not tightly coupled with changes in conductance.

During the early boll-filling period (mid- to late-July), leaves from the 11th most-recent node and sympodial leaves from any position typically were under low photosynthetic photon flux density (PPFD) levels (less than 350 umoles photons m^{-2} s^{-1}), resulting in net photosynthetic rates ranging from near 0 to about 25% (5 to 6 umol CO_2 m^{-2} s^{-1}) of the levels in main stem leaves from the 5th most-recent node.

A major problem in sampling the sympodial and lower canopy leaves for photosynthetic rates is the variability in light levels (transient high PPFD values, followed by major periods of low PPFD) in typical fruiting branches. In late-July, when sympodial leaves from intermediate-canopy positions (fruiting branch on 11th most-recent node) were found which were sunlit (greater than 800 umol photons m^{-2} s^{-1}) for a minimum of 15 minutes, average net photosynthesis was 17 umol CO_2 m^{-2} s^{-1}. During low sunlight conditions, however, much lower photosynthetic rates prevailed, resulting in relatively low photosynthetic productivity for sympodial leaves, particularly those at lower positions in the canopy. In all of these cases, the ratio of leaf conductance to photosynthesis was lower under low light conditions and with older leaves, indicating that stomata did not represent the major restriction to photosynthetic rates.

Influence of leaf age and position. Data collected during rapid leaf area development (June through mid-July) indicated that at ages 30, 37, 45, and 51 days after leaf initiation, sunlit main stem leaves had average photosynthetic rates which were 104%, 91%, 83%, and 67% of the rates measured in 20 day old main stem leaves (data not shown). Initiation of new main stem leaves essentially terminated during the first or second week of August in most irrigation treatments of the GC510 variety. From this point on, most of the illuminated leaves are aging at a time when the developing bolls have a high carbohydrate demand. Across all leaf positions, leaf photosynthetic rates showed an average 21% decline during a 20 day period in early to late August, with an additional 14% reduction during the next 11 days. The decline was more rapid in the severe water deficit treatment (T6).

Further analysis of this data will attempt to match average leaf photosynthetic data to leaf areas represented by each portion of the leaf canopy, and to evaluate data from Pima and Columnar types for significant differences from GC510 observations.

FUTURE PLANS: Further analysis of existing data is underway to determine the influence of types of cotton (GC510 vs. Columnar, Pima) on the observed responses. This information will be presented in future reports. In future experiments, the influence of leaf position and leaf age on cotton N levels will be measured directly through nitrate and Kjeldahl-N determinations, and indirectly through measurements of seasonal and age-related changes in leaf chlorophyll fluorescence. This information may provide additional guidelines for interpreting gas exchange measurements.

SUBSURFACE DRIP IRRIGATION OF COTTON: SEED COTTON AND LINT YIELDS

R.B. Hutmacher, C.J. Phene, K.R. Davis, T. Kerby,
M. Peters, S.S. Vail, R. Mead, D. Ballard, N. Hudson,
A. Bravo, D. Clark, M. Keeley

OBJECTIVES: The overall objectives of this project are to evaluate the responses of three types of cotton grown under subsurface drip irrigation and a narrow-row (76 cm row spacing) production system. Crop water requirements, use of stored soil water, root distribution and density, and specific crop growth, plant water status, and gas exchange responses to irrigation ranging from mild to moderate deficit irrigation in a clay loam soil will be determined in this study.

PROCEDURES: Cotton was grown during 1991 in a Panoche clay loam soil at the University of California West Side Field Station. Row spacing was 76 cm and the drip irrigation laterals were shanked in about 45 cm deep in alternate furrows, centered in the furrows. Details of the drip irrigation system, its operation and application amounts, and methods of determining grass reference evapotranspiration (ET_o) and crop coefficients are given in this volume in the report "Subsurface drip irrigation of cotton: Operational procedures". Six subsurface drip irrigation treatments were evaluated, with the treatments representing six different combinations of percentages of crop ET applied during specific portions of the growing season, as described in the "Operational Procedures" report on this project.

The responses of three types of cotton were evaluated within each of the six irrigation treatments: (1) a commercial narrow-row cotton (GC-510); (2) a columnar-type cotton out of the University of California cotton program; and (3) a "Pima" type (Pima S6). All three types of cotton were grown at the same planting density and cultural conditions were identical across the three cotton types. Each individual plot was split into 5 rows which were sprayed once per season with the growth regulator "PIX" (Mepiquat chloride), and 5 rows which were not sprayed ("No Pix" plots), with the PIX applied on July 9 at a rate of 0.5 pints per acre. Cotton lint yields were measured on 25 to 30 m sections of planted rows in each plot using a modified commercial spindle-picker harvester. Gin turnout percentages were determined at the UC/USDA cotton lab in Shafter, CA.

RESULTS: Within each irrigation treatment, there was no consistent yield response to the PIX application. The following discussion of responses to irrigation treatments generally is applicable to the average irrigation treatments response across PIX treatments.

Considering the relatively broad range of applied water across the six irrigation treatments, lint yields within each variety were all within a relatively narrow range. Pima lint yields ranged from 1944 to 2296 kg ha^{-1} with an average of 2098 kg ha^{-1}, GC510 ranged from 2128 to 2674 kg ha^{-1} with an average of 2440 kg ha^{-1}, Columnar ranged from 2193 to 2383 kg ha^{-1} with an average of 2298 kg ha^{-1} (Figs. 1, 2).

When applied water plus soil water depletion are summed to determine estimated crop evapotranspiration (ET_c) (see separate report entitled "Subsurface drip irrigation of cotton: Applied water, soil water use, evapotranspiration"), the variety GC-510 exhibited a trend toward a positive relationship between increasing lint yields and ET_c, while no significant relationship existed for the other two types of cotton (Fig. 3). Similar relationships were observed under both PIX treatments within each variety.

FUTURE PLANS: This experiment will be repeated in its entirety during the 1992 and 1993 growing seasons.

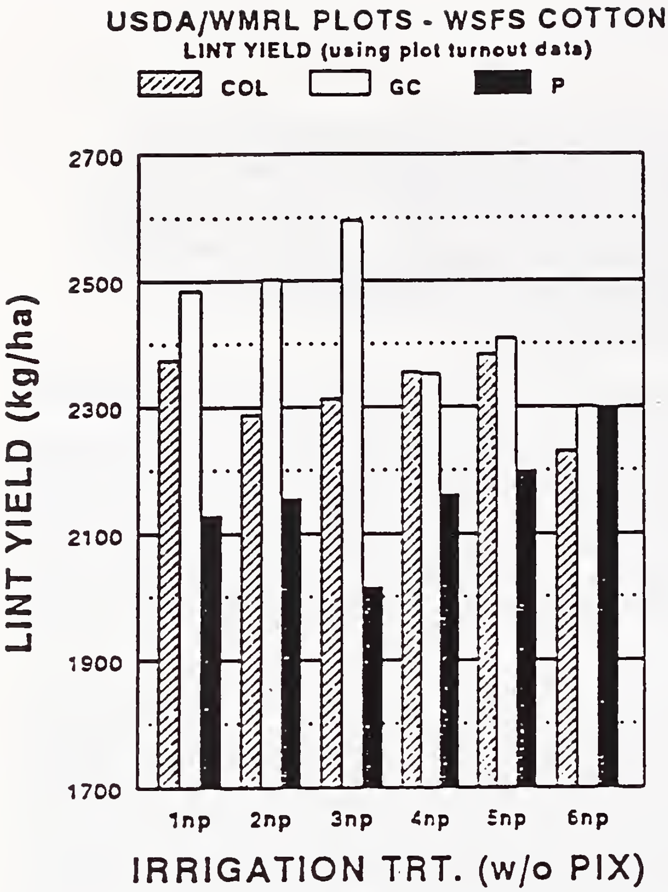


Figure 1.

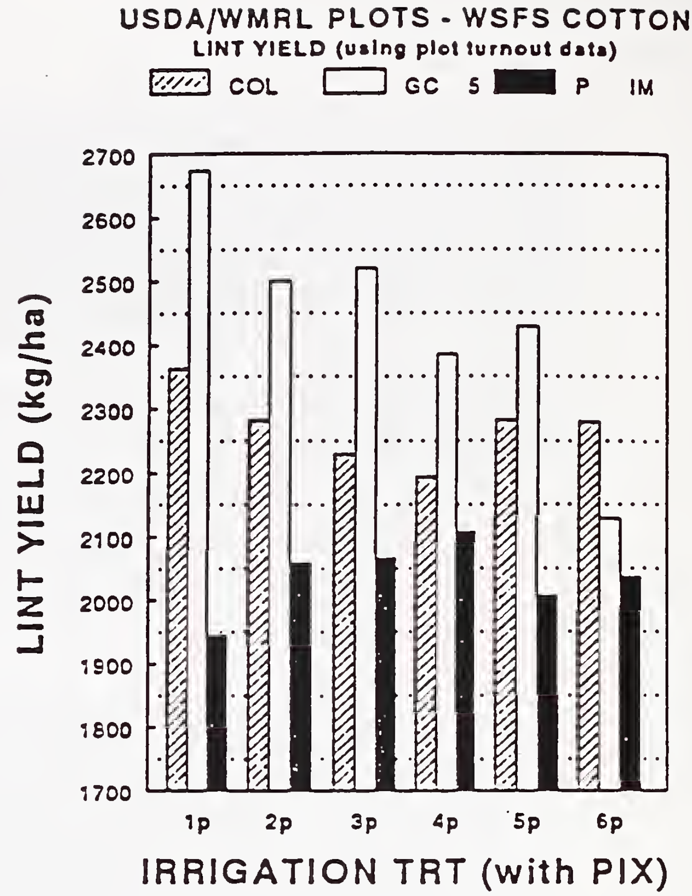


Figure 2.

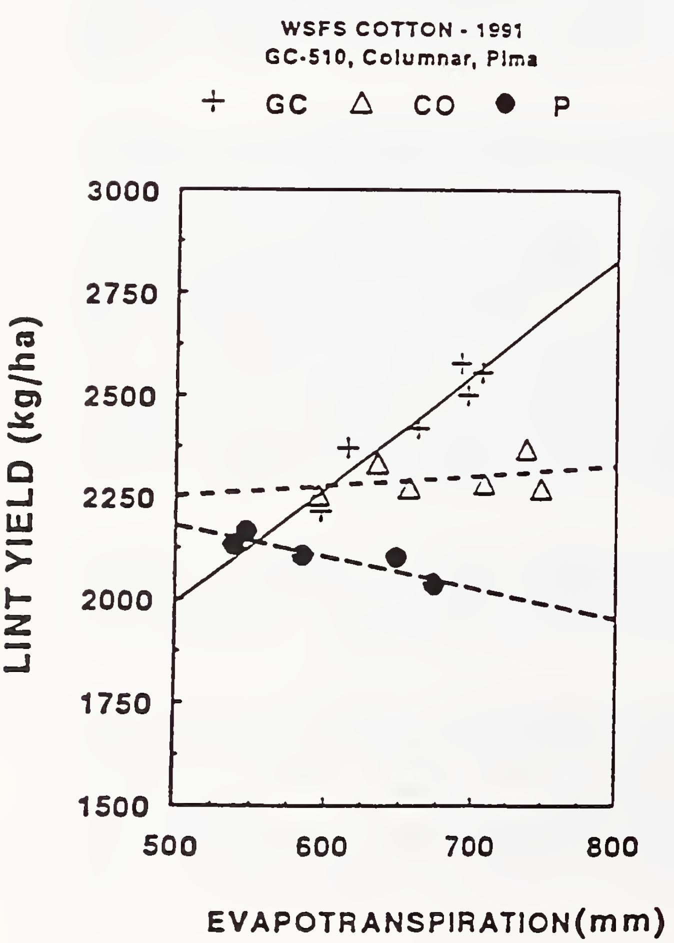


Figure 3.

Fig. 1. Cotton lint yields of "np" (plots not receiving a foliar PIX application) subsurface drip irrigated plots as a function of irrigation treatments(Treatment 1 through 6) and cotton type (Col=columnar; GC=GC510; P=Pima) at the West Side field Station in 1991.

Fig. 2. Cotton lint yields of "p" (plots receiving a foliar PIX application) subsurface drip irrigated plots as a function of irrigation treatments (Treatment 1 through 6) and cotton type (Col=columnar; GC=GC510; P=Pima) at the West Side Field Station in 1991.

Fig. 3. Lint yields versus crop evapotranspiration as a function of cotton type at the West Side Field Station in 1991. Lines shown for each cotton type were derived by linear regression.

SUBSURFACE DRIP IRRIGATION OF COTTON: PETIOLE N, P, AND K LEVELS DURING SEASON

R.B. Hutmacher, C.J. Phene, K.R. Davis, T. Kerby,
M. Peters, S.S. Vail, D. Ballard, N. Hudson,
A. Bravo, D. Clark, M. Keeley

OBJECTIVES: The overall objectives of this project are to evaluate the responses of three types of cotton grown under subsurface drip irrigation and a narrow-row (76 cm row spacing) production system. Crop water requirements, use of stored soil water, root distribution and density, and specific crop growth, plant water status, and gas exchange responses to irrigation ranging from mild to moderate deficit irrigation in a clay loam soil will be determined in this study.

PROCEDURES: Cotton was grown during 1991 in a Panoche clay loam soil at the University of California West Side Field Station. Row spacing was 76 cm and the drip irrigation laterals were shanked in about 45 cm deep in alternate furrows, centered in the furrows. Details of the drip irrigation system, its operation and application amounts, and methods of determining grass reference evapotranspiration (ET_0) and crop coefficients are given in this volume in the report "Subsurface drip irrigation of cotton: Operational procedures". Six subsurface drip irrigation treatments were evaluated, with the treatments representing six different combinations of percentages of crop ET applied during specific portions of the growing season, as described in the "Operational Procedures" report on this project.

Nutrient application rates and periods of application are described in "Subsurface drip irrigation of cotton: Operational Procedures" elsewhere in this report. N, P, and K were supplied through injection of calcium-ammonium nitrate and potassium nitrate, phosphoric acid, and potassium nitrate, respectively. Phosphoric acid was applied throughout the irrigation season, while calcium ammonium nitrate was applied during about the first three-quarters of the irrigation season and potassium nitrate during the last portion of the growing season. Calcium nitrate and potassium nitrate applications did not overlap in time. The rationale for these nutrient changes was to apply a higher N-content material (calcium ammonium nitrate) during the peak N demand period (early to mid-season) and apply a lower N-content material and K during the high K uptake period (mid- to late-season).

The responses of three types of cotton were evaluated within each of the six irrigation treatments: (1) a commercial narrow-row cotton (GC-510); (2) a columnar-type cotton out of the University of California cotton program; and (3) a "Pima" type (Pima S6). All three types of cotton were grown at the same planting density and cultural conditions were identical. Each individual plot was split into 5 rows which were sprayed once per season (July 9 at a rate of 0.5 pints per acre) with the growth regulator "PIX" (Mepiquat chloride), and 5 rows which were not sprayed ("No Pix" plots).

A minimum of twenty petioles were collected from each of three field replicate plots of each treatment evaluated. Samples were collected from the fourth or fifth most recent node prior to 0930 hours PDT at 7 to 10 day intervals throughout the season, dried at 50 to 55 C, and analyzed for NO^3-N, P, and K.

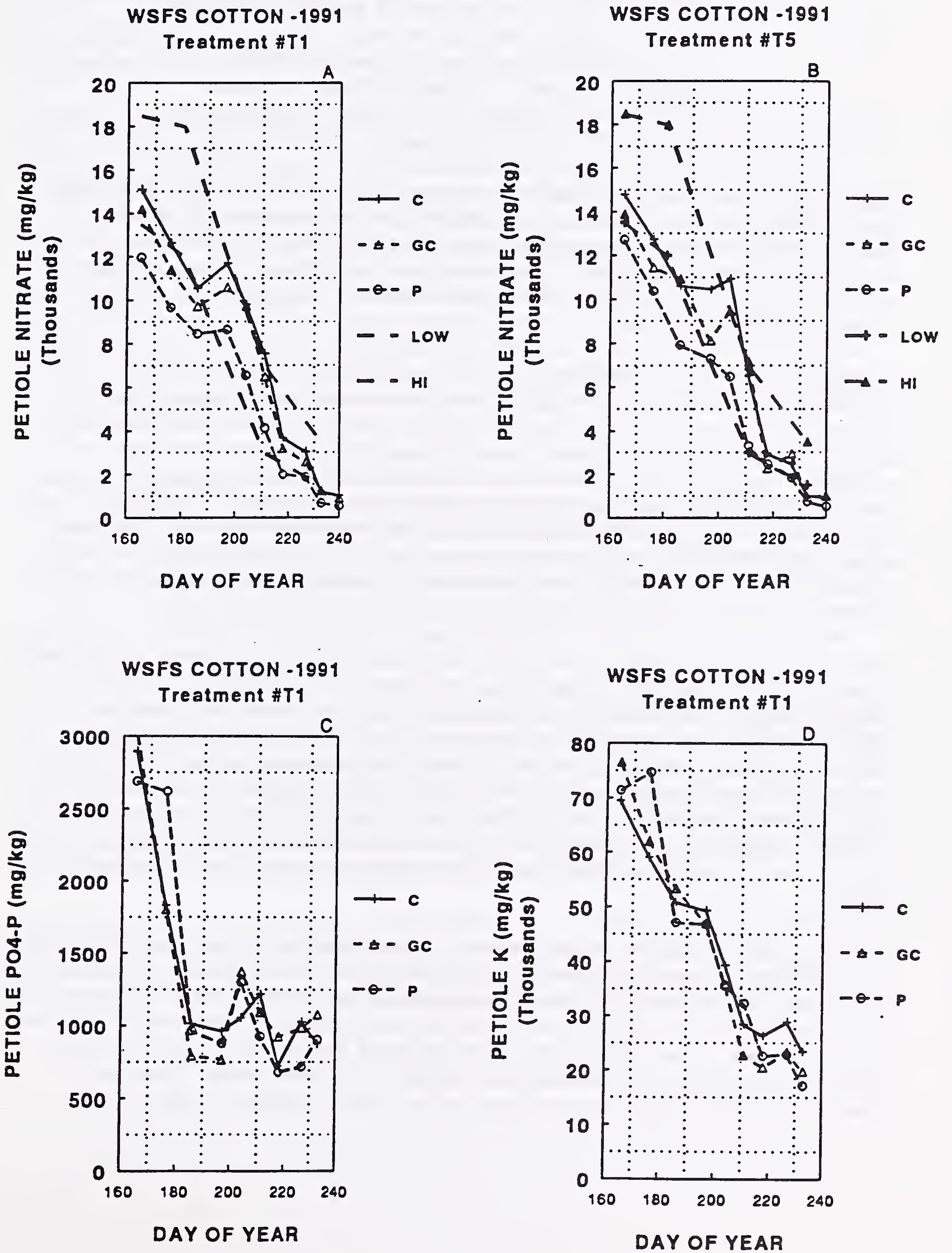
RESULTS: Even though water applications across treatments differed significantly (see "Subsurface drip irrigation of cotton: Applied water, soil water use, evapotranspiration"; this report), nutrient applications were uniform across all irrigation levels. There were few significant interactions between irrigation treatments and petiole nutrient status (data not shown).

Across all three types of cotton, petiole NO^3-N levels were generally below or at the low end of University of California recommended NO^3-N levels during the early to mid-season (prior to day 190) under both low water stress (treatment T1) and higher water stress (treatment T5) conditions (Fig. 1a, 1b). During mid-to late-season, petiole NO^3-N levels of the Acala types were closer to the low end of recommended levels. Petiole NO^3-N levels of Pima were usually significantly lower than in the Acala types, particularly in the early- to mid-season period (days 160 to 210). Although not all soil nutrient data has been fully analyzed, available data indicates that soil N levels at planting were quite low, suggesting little carryover of N from previous crops.

Petiole P and K levels similarly were on the low end of the "sufficient" levels identified by the University of California in prior studies (Figs. 1c and 1d). Since lint yields were high in all plots despite what generally could be regarded as barely sufficient petiole nutrient levels during some growth stages, this data may indicate a need to reevaluate guidelines for petiole nutrient levels for drip irrigated cotton.

FUTURE PLANS: This experiment will be repeated in its entirety during the 1992 and 1993 growing seasons. In future experiments, the influence of leaf position and leaf age on cotton N levels will be measured directly through nitrate and Kjeldahl-N determinations, and indirectly through measurements of seasonal and age-related changes in leaf chlorophyll fluorescence. The lower petiole nutrient levels observed in Pima relative to the Acala types will be investigated in future studies to determine the consistency of this response across years.

Figure 1. Petiole levels of nitrate, phosphate, and potassium as a function of day of year for columnar (C), GC510 (GC), and Pima (P) types of drip irrigated cotton at the West Side Field Station in 1991. Shown are: (1a) petiole nitrate for treatment T1; (1b) petiole nitrate for T5; (1c) petiole phosphate for T1; and (1d) petiole potassium for T1. Upper (HI) and lower (LOW) dashed lines in Figs. 1a, 1b indicate "excess" and "deficient" petiole nitrate guidelines of the University of Calif.



SUBSURFACE DRIP IRRIGATION OF COTTON: ROOT LENGTH DENSITY AND DISTRIBUTION AS AFFECTED BY DEPTH IN SOIL AND DISTANCE FROM EMITTERS

C.J. Phene, R.B. Hutmacher, K.R. Davis, T. Kerby,
J. Misaki, A. Nevarez, C. Ament, R. Mead, D. Ballard,
N. Hudson, C. Hawk, S.S. Vail, D. Clark, M. Keeley

<u>OBJECTIVES</u>: The overall objectives of this project are to evaluate the responses of three types of cotton grown under subsurface drip irrigation and a narrow-row (76 cm row spacing) production system. Crop water requirements, use of stored soil water, root distribution and density, and specific crop growth, plant water status, and gas exchange responses to irrigation ranging from mild to moderate deficit irrigation in a clay loam soil will be determined in this study.

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Soil samples for determination of root length density and weight were collected in plots from variety GC510 in three field replications each of treatments T1, T4, and T6. Samples were collected during mid-September, 1991, representing the end-of-season root distribution. A total of six sample locations were identified in each plot, with three of the sample sites situated along a line perpendicular to the drip lateral, starting adjacent to an emitter (site A1); the next sample location in line with the plant row (site A2), and the next location in the dry (no drip line) furrow (site A3). The other three sample locations (designated as M1, M2, M3) correspond to locations A1, A2, A3 in terms of position relative to the drip lateral, however, the M1 position is midway on the lateral between emitters (about 45 cm from the emitter).

In each of these six locations per plot, soil samples were collected in 15 cm increments to a depth of 270 cm using a Giddings sample tube. Soil samples were collected and stored under refrigeration until processed. Subsamples were collected for determination of soil water content, and bulk soil wet weights and dry weights were determined. Processing the samples for determination of root length density involved physical washing of the soil/root samples using dilute acetic acid to aid in floating and separation of organic matter. Roots were separated from other organic matter by hand, stained with a dilute methyl violet, and root

length measured using a calibrated video area meter. Root length density was calculated using measured root lengths and soil dry weights.

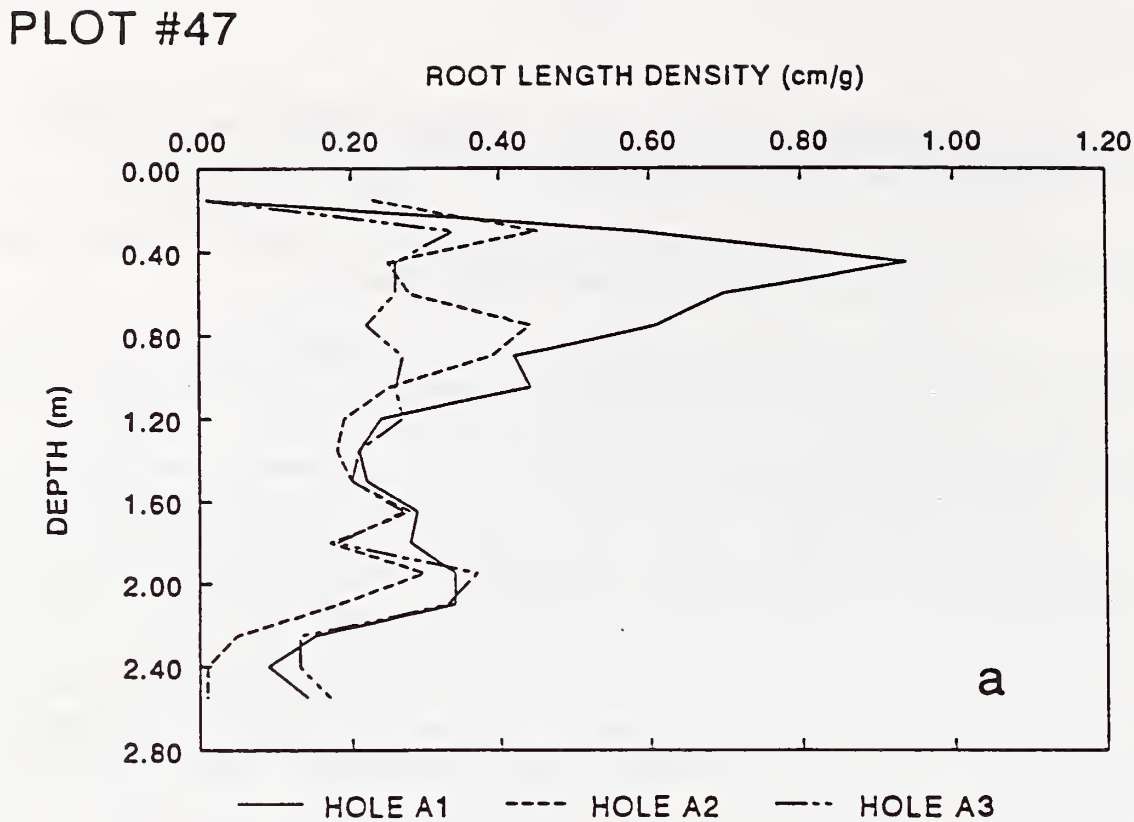
Root samples collected using the above procedure were dried at 55 C for 24-48 hours, then weighed and expressed as root dry weight per unit weight of soil.

RESULTS: Effects of Sampling Location Within Beds: At sampling locations within each plot, root length density (RLD) was generally highest at the 45 cm and 60 cm depths, with the lowest at the surface sample (0 to 15 cm depth) and below 2 m depth. Examples of calculated root length density as a function of depth in the soil profile are presented for treatment T1 (GC510 variety only) in Figures 1a and 1b. In both location A1 and M1 (closest to the emitter) in most plots, RLD at the 45 to 75 cm depths was significantly higher than in corresponding A2, A3, M2, M3 sampling locations. The consistency of this root proliferation closest to the lateral will be evaluated during the 1992 season. Since the drip tubing was shanked in during the winter preceding the 1991 season, it is possible that the physical disruption of the soil at that time favored localized root development more during the 1991 season than will be seen in future years. At other depths, RLD's were generally similar across the sample locations, with values ranging from 0.2 to 0.45 cm root g^{-1} soil even at 2 m depth.

Effects of Irrigation Treatments: Soil profile water contents in the upper 2m of the profile were quite high at the beginning of the 1991 growing season, and this undoubtedly had an impact on rooting patterns of the more severe deficit irrigation treatments. Soil water content will be closely monitored in future studies to relate measured RLD to soil water content. Root dry weights were positively correlated with calculated root length density, but r^2 values for linear regressions between them were generally less than 0.65 and were not significantly correlated at three of the six sample locations (averaged across all plots and treatments).

Preliminary analyses indicated that RLD's were similar across treatments at the A1 and M1 locations (data not shown). Limited irrigation treatment RLD data is shown in Fig. 2 as the difference in RLD's for treatments T4 or T6 and T1. A positive value indicates RLD higher than in treatment T1, a negative value in Fig. 2 indicates lower RLD. In the A2/M2 and A3/M3 locations, RLD's in the upper 1 m of the soil profile of T4 treatments tended to be higher than in T1 treatments, however, the averages are quite variable with depth. Statistical analysis of this data has not been completed at the time of this report.

FUTURE PLANS: This experiment will be repeated in its entirety during the 1992 and 1993 growing seasons. Samples for determination of root distribution will be collected at three growth stages in the 1992 season: early flowering (late June), mid-flowering/early boll development (late July-early August), and late-season (early September).



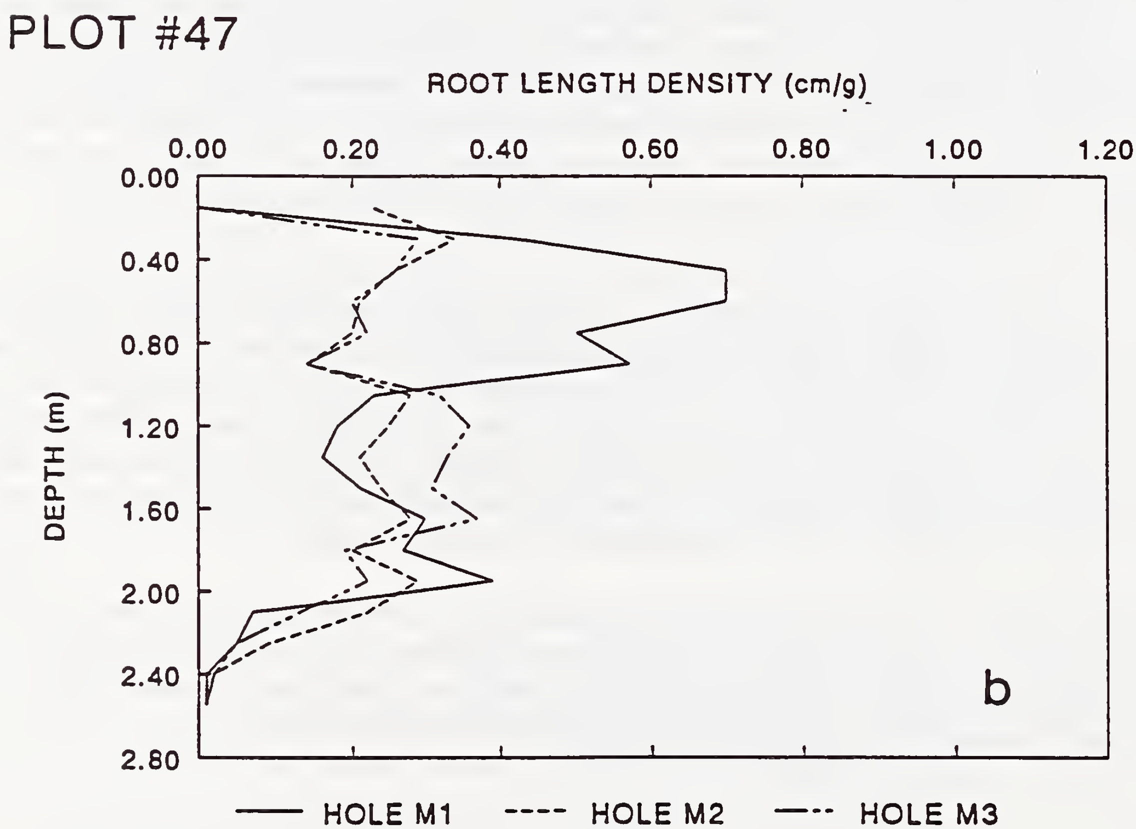
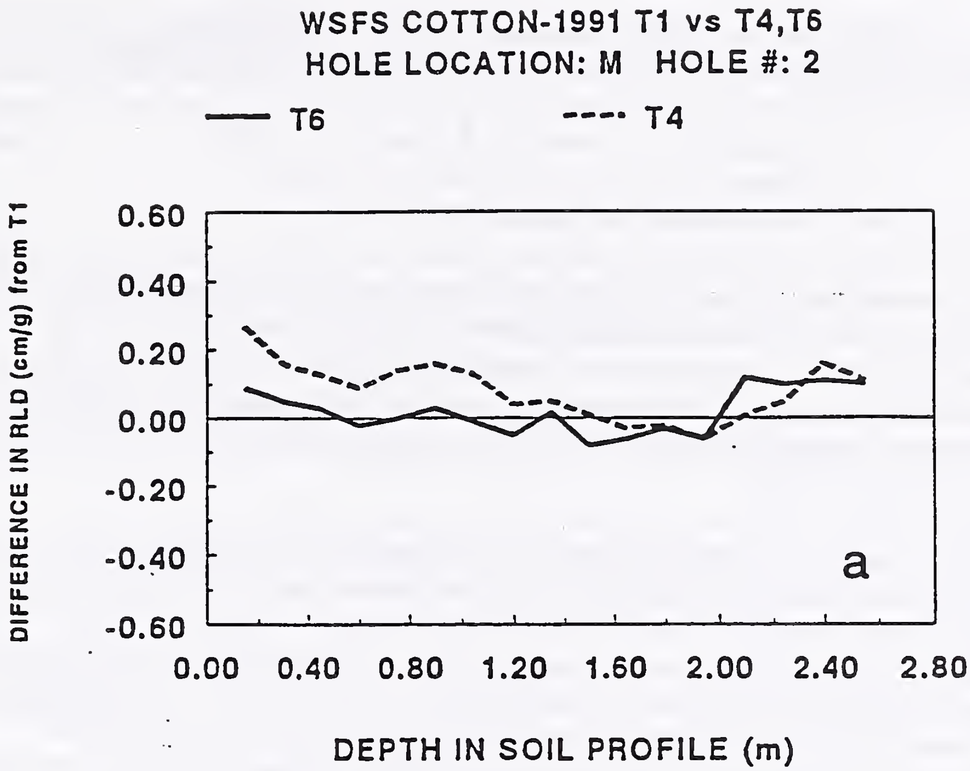


Figure 1. Root length density as a function of depth in the soil profile for: (a) sample holes A1, A2, A3; and (b) sample holes M1, M2, M3 in treatment T1 of GC510 cotton at the West Side Field Station in mid-September of 1991.



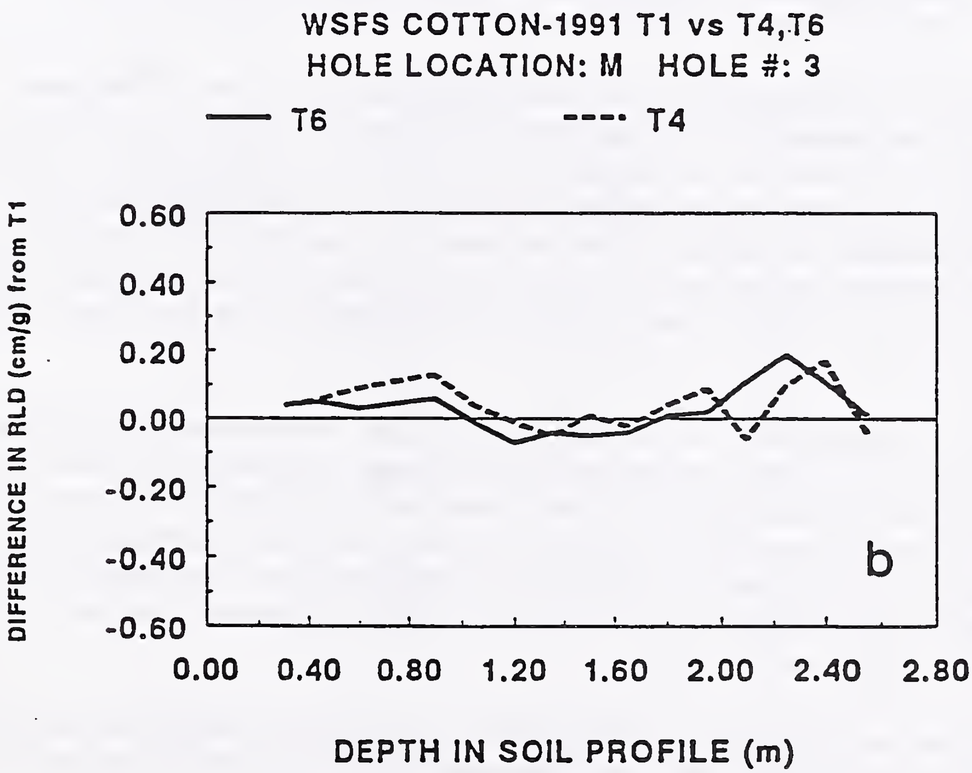


Figure 2. Difference in root length density between treatment T1 and T4 or T6 as a function of depth in the soil profile for sample holes (a) M2 and (b) M3 (averaged across all field replicates) in GC510 cotton at the West Side Field Station in mid-September of 1991.

SUBSURFACE DRIP IRRIGATION OF COTTON: GROWTH, LEAF AREA AND DRY MATTER PRODUCTION

R.B. Hutmacher, C.J. Phene, K.R. Davis, T. Kerby,
M. Peters, S.S. Vail, D. Ballard, N. Hudson,
D. Clark, M. Keeley, A. Bravo

OBJECTIVES: The overall objectives of this project are to evaluate the responses of three types of cotton grown under subsurface drip irrigation and a narrow-row (76 cm row spacing) production system. Crop water requirements, use of stored soil water, root distribution and density, and specific crop growth, plant water status, and gas exchange responses to irrigation ranging from mild to moderate deficit irrigation in a clay loam soil will be determined in this study.

PROCEDURES: Cotton was grown during 1991 in a Panoche clay loam soil at the University of California West Side Field Station. Row spacing was 76 cm and the drip irrigation laterals were shanked in about 45 cm deep in alternate furrows, centered in the furrows. Details of the drip irrigation system, its operation and application amounts, and methods of determining grass reference evapotranspiration (ET_0) and crop coefficients are given in this volume in the report "Subsurface drip irrigation of cotton: Operational procedures". Six subsurface drip irrigation treatments were evaluated, with the treatments representing six different combinations of percentages of crop ET applied during specific portions of the growing season, as described in the "Operational Procedures" report on this project.

The responses of three types of cotton were evaluated within each of the six irrigation treatments: (1) a commercial narrow-row cotton (GC-510); (2) a columnar-type cotton out of the University of California cotton program; and (3) a "Pima" type (Pima S6). All three types of cotton were grown at the same planting density and cultural conditions were identical across the three cotton types. Each individual plot was split into 5 rows which were sprayed once per season with the growth regulator "PIX" (Mepiquat chloride), and 5 rows which were not sprayed ("No Pix" plots), with the PIX applied on July 9 at a rate of 0.5 pints per acre.

Cotton growth and development were monitored throughout the season using measurements of plant height, number of nodes, nodes above white bloom, and during five measurement dates, complete plant growth analysis involving flower and boll counts, plant component dry weights, and leaf area. In addition, although not reported here, Dr. Tom Kerby, Mark Keeley and staff of the University of California also monitored plant development and growth through modified plant mapping procedures during much of the season. That data will be available in future reports on this project.

RESULTS: Cotton evapotranspiration (ET) generally was highest in irrigation treatment T1, lowest in T6, and intermediate in the other treatments (see "Subsurface drip irrigation of cotton: Applied water, soil water use, and ET" elsewhere in this report). Most growth parameters measured during July and August reflected these treatment differences in applied

water and levels of plant water deficits, with reduced plant heights, slight reductions in main stem nodes, lower leaf area, and lower total dry matter in the more severely water-stressed treatments (ie. treatment T5, T6). Averages for these parameters as of August 21 are shown in Table 1.

Application of the growth regulator "PIX" (mepiquat chloride) had a consistent, albeit small influence on plant height, number of nodes, and leaf area (data not shown). The greatest impact of Pix applications was in treatments receiving higher water applications (treatments T1, T2, T3), in which leaf area index and plant height as of August 21 were reduced across all three cotton types by an average of 7% and 9%, respectively, with Pix applications. Similar responses were seen across all three types of cotton. Responses to Pix applications in the lowest water application treatment (T6) were not significant (data not shown).

Within the GC510 plots, total dry matter in late-August or mid-September was positively correlated ($r^2 = 0.69$, $r^2 = 0.79$, respectively) with lint yields, although lint yields were high in all treatments and did not vary by more than 20% across all plots.

FUTURE PLANS: This experiment will be repeated in its entirety during the 1992 and 1993 growing seasons.

Table 1. Number of nodes, plant height, leaf area index, and total above-ground dry matter for three types of cotton (GC510, Columnar C2, Pima S6) grown at the West Side Field Station in 1991 as a function of irrigation treatment. All data shown is for "no Pix" treatments measured on August 21, 1991.

Cotton type	Irrigation treatment	Number of main stem nodes	Plant height (cm)	Leaf area index ($m^2\ m^{-2}$)	Total above-ground dry matter ($T\ ha^{-1}$)
GC510	T1	21.3	100	4.24	14.1
	T2	20.7	95	3.69	12.4
	T3	21.1	91	3.55	13.1
	T4	20.5	89	3.64	13.4
	T5	20.5	85	3.35	12.7
	T6	20.1	82	3.18	11.6
Pima	T1	21.5	95	3.76	12.9
	T4	20.1	89	3.56	12.2
	T6	19.8	78	2.87	12.7
Columnar	T1	21.6	107	4.14	14.3
	T4	21.3	101	3.79	14.0
	T6	20.1	94	3.57	13.1

WATER MANAGEMENT REQUIREMENTS OF SUBSURFACE DRIP IRRIGATION IN THE IMPERIAL VALLEY: FORAGE ALFALFA STUDY: OPERATIONAL PROCEDURES

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K.R. Davis, R.A. Schoneman, A. Bravo

OBJECTIVES: The alfalfa subsurface drip irrigation/furrow irrigation project at the Irrigated Desert Research Station in Brawley, CA is a five-year evaluation of alfalfa water requirements and the long-term influence of irrigation management on soil accumulations of salts and potentially yield-limiting specific ions. This experiment focuses on the comparison of crop responses, irrigation water requirements, and salinity accumulations as affected by subsurface drip versus furrow irrigation. In addition, the influence of two drip lateral spacings will also be evaluated.

PROJECT COOPERATORS: The five year study is being conducted in Brawley, CA in cooperation with the USDA-ARS Salinity Laboratory, Riverside, CA; the USDA-ARS Irrigated Desert Research Station (IDRS), Brawley, CA; the Imperial Valley Conservation Research Center Committee (IVCRCC); the Imperial Irrigation District (IID); the USDA-ARS Western Cotton Research Laboratory, Phoenix, AZ; the Metropolitan Water District of Southern California (MWD).

PROCEDURES: Three replications of each of five irrigation treatments are under investigation in this experiment. There are two drip lateral spacing treatments, 40 inch (1.02 m) and 80 inch (2.04 m), with the drip laterals placed 40 cm below the center of each bed, with 1.02 m and 2.04 m beds, respectively. Two different types of drip tubing are used with each row spacing: (a) pressure-compensating in-line emitters on 20 mm tubing; and (b) turbulent-flow in-line emitters made out of herbicide-impregnated plastic. Both emitter types have a nominal flow of 2 L h^{-1} at 18 to 20 psi and are spaced 40 inches (1.02 m) apart on the drip lateral. Treatments are designated as follows: T1 = 1.02 m lateral spacing with type (a) emitters (described above); T2 = 1.02 m spacing with type (b) emitters; T3 = 2.04 m spacing with type (a) emitters; T4 = 2.04 m spacing with type (b) emitters; and T5 = furrow irrigation.

All drip and furrow irrigation treatments are instrumented with electronic flow meters, and the drip system also was instrumented with pressure transducers which are connected to the Fresno WMRL location via a datalogger/computer system. A 3m by 3m by 1.5 m deep weighing lysimeter which is also irrigated via subsurface drip irrigation is located in the central part of the field. The lysimeter serves both as an ET-measuring instrument and as an irrigation controller, with a 1 mm irrigation initiated in both the lysimeter and in treatments T1 through T4 following each 1 mm of measured lysimeter evapotranspiration (ET).

Access tubes are located in the southern and northern sectors of each plot, with soil water content monitored by neutron attenuation to determine changes during each harvest cycle.1

The design of the irrigation system and data acquisition system was finalized, parts ordered, and construction started in December, 1990 through March, 1991. Drip system installation was completed in March, 1991, and the crop was planted on April 2 to 4. Approximately 230 mm of post-plant irrigation was applied to all treatments using sprinklers. The drip irrigation and furrow irrigation treatments were initiated coinciding with the first furrow irrigation applied in late May. The first harvest was in late June.

Alfalfa harvesting equipment (swather, rake, and wire baler) were purchased jointly by the project (WMRL) and the Imperial Irrigation District in order to allow a commercial-type harvest in these plots. Initially, a commercial operator was used to pick up bales, but following repeated problems in coordinating schedules for timely bale pickup and compaction problems associated with trucks, an alternative method was devised. Bales are picked up and individually weighed and placed on a trailer for removal from the field. Forage yields are based on actual bale weights. Yields are corrected to a constant water content. Samples for determination of forage yield quality components are collected from random bales from each plot.

Water samples are collected once or twice per month to determine any seasonal changes in quality. Irrigation water quality averaged the following:

Electrical conductivity (EC):	1.15 dS/m
Boron:	.13 to 0.25 mg B/L
Chloride:	2.5 to 3.5 meq Cl/L
Calcium:	80 to 120 mg Ca/L
Magnesium:	30 to 35 mg Mg/L
low in Fe and Mn	

Soil samples are to be collected to a depth of 2 to 2.5 m in all plots once per year (in October/November) to assess long-term impact of irrigation practices on accumulation of salts and other chemical constituents. Periodic soil samples will be collected as time and labor permits to evaluate within-season changes in surface soil (top 0.75 m of the profile) salinity and the potential need for leaching.

<u>FUTURE PLANS</u>: Plans call for the alfalfa experiment to be continued during the 1992 through 1995 seasons.

WATER MANAGEMENT REQUIREMENTS OF SUBSURFACE DRIP IRRIGATION IN THE IMPERIAL VALLEY: FORAGE ALFALFA STUDY: APPLIED WATER AND ALFALFA YIELDS

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OBJECTIVES: The alfalfa subsurface drip irrigation/furrow irrigation project at the Irrigated Desert Research Station in Brawley, CA is a five-year evaluation of alfalfa water requirements and the long-term influence of irrigation management on soil accumulations of salts and potentially yield-limiting specific ions. This experiment focuses on the comparison of crop responses, irrigation water requirements, and salinity accumulations as affected by subsurface drip versus furrow irrigation. In addition, the influence of two drip lateral spacings will also be evaluated.

PROJECT COOPERATORS: The five year study is being conducted in Brawley, CA in cooperation with the USDA-ARS Salinity Laboratory, Riverside, CA; the USDA-ARS Irrigated Desert Research Station (IDRS), Brawley, CA; the Imperial Valley Conservation Research Center Committee (IVCRCC); the Imperial Irrigation District (IID); the USDA-ARS Western Cotton Research Laboratory, Phoenix, AZ; the Metropolitan Water District of Southern California (MWD).

PROCEDURES: Treatments were as described in "Water management requirements of subsurface drip irrigation in the Imperial Valley: Operational Procedures" (elsewhere in this report). Three replications of each of five irrigation treatments are under investigation in this experiment. There are two drip lateral spacing treatments, 40 inch (1.02 m) and 80 inch (2.04 m), with the drip laterals placed 40 cm below the center of each bed, with 40 inch and 80 inch beds, respectively. Two different types of drip tubing were used with each row spacing: (a) pressure-compensating in-line emitters on 20 mm tubing; and (b) turbulent-flow in-line emitters made out of herbicide-impregnated plastic. Both emitter types have a nominal flow of 2 L h^{-1} at 18 to 20 psi. Emitter spacing along the laterals is 40 inches (1.02 m) in both types of tubing.

Forage yields are based on actual bale weights from commercial harvesting equipment. Yields are corrected to a constant water content. Samples for determination of forage yield quality components were collected from random bales from each plot. Plant water status is monitored using infrared thermometry and the Crop Water Stress Index (CWSI) method, while soil water content was determined by neutron attenuation using access tubes located in the northern and southern section of each plot.

Phosphoric acid was continuously injected in all drip plots to achieve a final concentration of 15 mg P/L in the irrigation water. An initial broadcast P application was made in all plots and side-dress applications were made in furrow-irrigated plots.

<u>RESULTS</u>: This report will cover harvesting and field operations during the period from planting of the alfalfa in April, 1991 through December, 1991. Total applied water, including sprinkler irrigation for establishment and drip or furrow irrigation in 1991 are shown in Fig. 1, ranging from a low of approximately 1120 mm in treatment T2 to approximately 1300 mm in the furrow-irrigated treatment (T5). 1991 forage yields in the 2.04 m drip lateral spacing treatments (T3, T4) averaged 17% lower than in 1.02 m lateral spacing treatments (T1, T2), while furrow treatment (T5) averaged 33% lower than T1 and T2 (Fig. 2). No significant differences in yields existed between treatments representing types of drip tubing, (T1 vs. T2 or T3 vs. T4).

In the lysimeter, frequent irrigation could be maintained throughout the harvest cycle to sustain a high soil water content, which resulted in extremely high forage yields and rapid regrowth following each harvest. In the furrow plots, typical practices were followed, which include application of the last irrigation 5 to 7 days prior to harvest followed by the next irrigation immediately after the harvested bales are removed. In the drip plots, problems with malfunctioning or shallow emitters (in less than 1 to 2% of the field area) resulted in wet areas at the soil surface which caused problems with harvesting equipment. In order to limit compaction, irrigation in the drip plots was scaled down to 25% to 50% of lysimeter-application amounts during each harvest cycle (4 to 6 days prior to harvest through removal of bales). Work will be done to determine the degree to which malfunctioning equipment and/or depth of lateral installation are the source of the wet area problems.

In the furrow irrigated plots, neutron probe-determined soil water contents were used in conjunction with water applications and field observations to schedule irrigations. In both furrow and drip irrigation treatments, crop water uptake exceeded applied water during the last four to five months of 1991 and through early 1992, resulting in a gradual depletion of stored soil water in the third through seven foot depth in the soil profile. Soil samples were collected to monitor changes in chemical constituents (salinity, etc.) as a function of irrigation treatments, locations within beds, and depth in the soil profile. Samples were collected in September and November of 1991 and February of 1992 in field F-2. This data has not been fully analyzed and summarized to date.

<u>FUTURE PLANS</u>: This experiment will continue through 1994/1995 seasons.

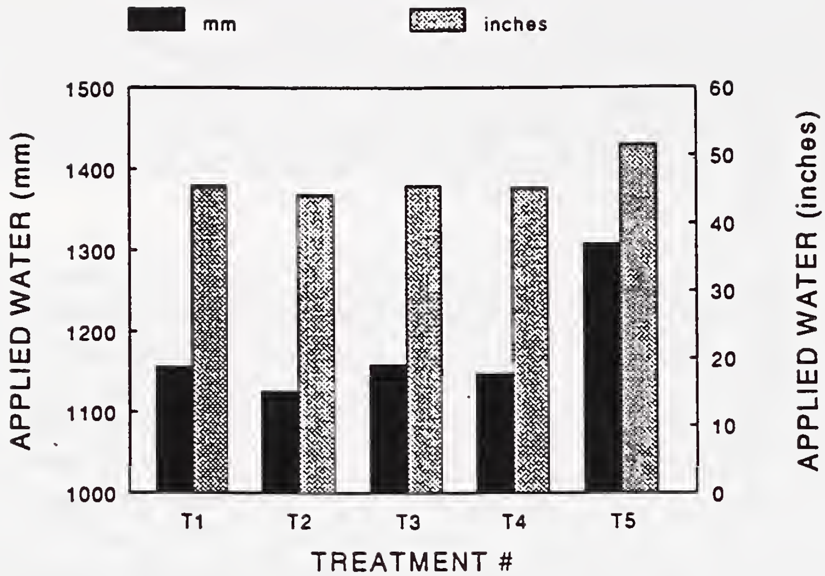

Figure 1. Applied water (mm or inches) in alfalfa irrigation treatments at Brawley, Ca.

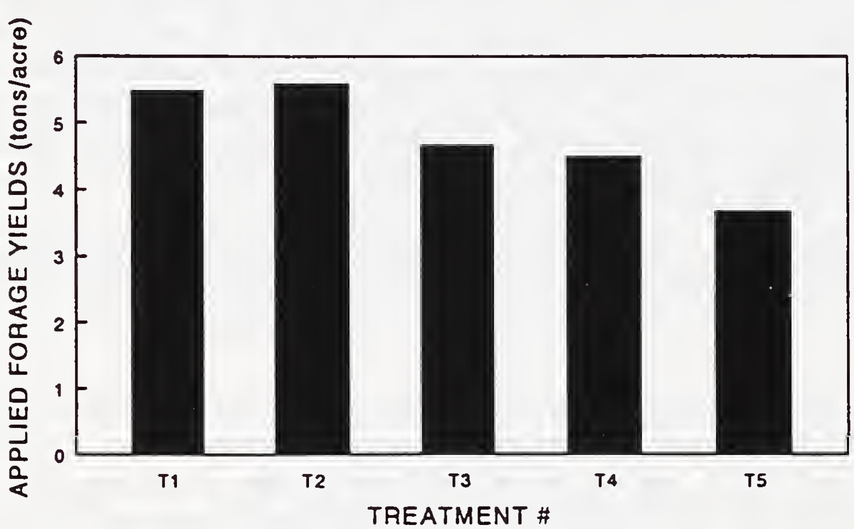

Figure 2. Total alfalfa yield (corrected to constant moisture percentage) in 1991 in alfalfa irrigation treatments at Brawley, Ca.

WATER MANAGEMENT REQUIREMENTS OF SUBSURFACE DRIP IRRIGATION IN THE IMPERIAL VALLEY: ROW CROP STUDY: CANTALOUPE AND LETTUCE

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OBJECTIVES: The row crop subsurface drip irrigation/furrow irrigation project at the Irrigated Desert Research Station in Brawley, CA is a five-year evaluation of water requirements of select annual crops and the long-term influence of irrigation management on soil accumulations of salts and potentially yield-limiting specific ions. This experiment focuses on the comparison of crop responses, irrigation water requirements, and salinity accumulations as affected by subsurface drip irrigation. Initial plans were to include cantaloupe, processing tomatoes, cotton and lettuce in this study, but plans were scaled back to lettuce and cotton due to white fly infestations plaguing the Imperial Valley in 1991, 1992.

PROJECT COOPERATORS: The five year study is being conducted in Brawley, CA in cooperation with the USDA-ARS Salinity Laboratory, Riverside, CA; the USDA-ARS Irrigated Desert Research Station (IDRS), Brawley, CA; the Imperial Valley Conservation Research Center Committee (IVCRCC); the Imperial Irrigation District (IID); the USDA-ARS Western Cotton Research Laboratory, Phoenix, AZ; the Metropolitan Water District of Southern California (MWD).

GENERAL PROCEDURES: The F-3 field at the USDA-ARS Irrigated Desert Research Station in Brawley, CA was prepared in beds 1.52 m in width. Drip tubing with a wall thickness of 20 mil was installed at a depth of 40 cm below the soil surface in the center of each bed. The emitters are spaced 1.02 m apart on the lateral and are of a turbulent-flow design with a nominal output of 2 L h^{-1}. There are four irrigation treatments with four replications in a randomized complete block design. Each irrigation treatment has electronic water meters and pressure transducers which can be monitored continuously using a data logger/computer control system accessible through the USDA/WMRL in Fresno or via modem at any location. Each plot consists of six 1.02 m beds 80 m in length. A fertilizer injection system consisting of a mixing tank and proportional flow injectors was used for N, P, and K injections through the drip irrigation system. Sixteen access tubes were installed (one per plot) to allow soil water content measurements using neutron attenuation techniques.

Cantaloupe Methods and Results. Following completion of the installation and testing of the irrigation system, seed of the variety "Topmark" was planted in August, 1991. Irrigation treatments following a sprinkler application for germination were as follows for treatments T1, T2, T3, and T4, respectively: 60%, 80%, 100%, and 120% of estimated crop evapotranspiration (ET_c). ET_c was estimated based on a crop coefficient derived using Imperial Valley and Arizona data in combination with grass reference ET determined at the Calipatria CIMIS site. Extensive efforts were required to spray for whiteflies through the

month of September, but were ineffective. The plants were severely stunted and the project on cantaloupes was terminated on October 4. It was determined that a lettuce crop would be substituted as the fall/winter crop.

Lettuce Methods and Results. A late-season lettuce variety ("Winterhaven") was planted, three rows per 1.52 m bed, on November 13, 1991. Pre-plant fertilizer (11-48-0) was applied at a rate of 60 kg ha^{-1} uniformly across all treatments. A total of 104 kg P ha^{-1} and 159 kg N ha^{-1} was applied, with all fertilizer other than pre-plant applied through the drip system. The seed was germinated and the crop sprinkled up with 115 mm of water. During the period from planting through harvest, 73 mm of rain fell. Irrigation treatments were altered to apply 70%, 85%, 100%, and 130% of ET_c.

Lettuce yields were determined from six hand-harvested 6.1 m sections of row in each plot, with all three rows per bed harvested, lettuce heads counted, and all heads weighed. Yields were collected 5 to 7 days prior to when a commercial-type harvest would have begun in order to clear the field and accommodate a "desired" planting date for the cotton crop which immediately followed the lettuce. Soil samples were collected at the beginning and end of the lettuce experiment to characterize the influence of variable irrigation rates on accumulation of salts and chemical constituents in the soil profile.

Actual water applications through the drip system totalled 95, 112, 129, and 172 mm in treatments T1 through T4, respectively. Soil water depletion (-) or addition (+) during the season ranged from about -35 mm in treatment T1 to +12 mm in T4, resulting in total seasonal water (sprinkler and drip irrigation plus rainfall plus soil water changes) ranging from 308 mm in treatment T1 to a high of 338 mm in T4. This narrow range in calculated ET_c occurred in spite of the 77 mm difference in applied water between T1 and T4.

Whitefly damage was relatively uniform across all plots during the first three weeks after germination. Due to the late planting date, however, whitefly pressure was relatively minor during the majority of the season and did not exert a major influence on lettuce yields. Seedling survival was excellent in all plots, and plant populations were not significantly different across irrigation treatments. Lettuce yield responses to irrigation treatments are shown in Table 1.

Table 1. Lettuce yields (fresh weights) in subsurface drip irrigation treatments in Brawley, CA in 1991-1992 experiment.

Treatment #	Lettuce Fresh Weight Yields (Metric Tons ha^{-1})	Average Lettuce Head Fresh Weight (kg)
T1	47.3	.66
T2	48.2	.64
T3	50.7	.63
T4	46.9	.62

None of these yields or average head weights were significantly different across treatments. The relatively high soil water storage at the beginning of the season in the upper 1.5 m of the profile in all plots contributed to the lack of treatment influence on lettuce yields.

Cotton (1992) Methods and Results. For 1992, an irrigation control system was installed during the period between the lettuce harvest and planting of the cotton crop in March, 1992. The irrigation control system consists of a group of field-installed matric potential sensors similar to those originally developed by C.J. Phene et al., which were installed at a fixed distance from the subsurface drip emitters and connected through a communications system to a data logger which controls the irrigation system. The system used and procedures proposed for the 1992 experiment are detailed elsewhere in this report (see Cardon et al.).

FUTURE PLANS: In spite of continuing whitefly pressure, lettuce is likely to remain the principal winter crop in the row crop study for the next two years, after which time onions may be considered for fall planting. In future irrigation trials with subsurface drip irrigation of lettuce, a broader range of water applications will be utilized in an effort to determine the lower limit in applied water which will give an acceptable yield response. A mid-season (mid-October) variety and planting date will be used in 1992.

THE EFFECT OF ROOT APPLICATION OF PIX TO COTTON

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<u>OBJECTIVES</u>: To determine if root applied PIX affects the general morphology of the cotton plant to the extent as foliar application of PIX.

<u>PROCEDURES</u>: Cotton was grown in water culture and potted soil under greenhouse conditions. In the water culture, the plants were grown in a temperature controlled greenhouse with a 16 h day of 850 μmol $m^{-1}S^{-1}$ irradiance and 24°/18° C day/night temperature. Two-week old cotton seedlings were transplanted into 4 L pots containing 0.2 strength complete Hoagland's nutrient solution No. 2. Treatments consisted of eight PIX treatments: Trt. 1 = No PIX; Trt. 2 = 2x normal foliar application (NFA) (based upon 1 pint/acre); Trt. 3 = 1x NFA applied to water solution; Trt. 4 = 3x 50% strength NFA applied to water solution; Trt. 5 = 6x 50% NFA applied to water solution; Trt. 6 = 6x 20% NFA applied to water solution; Trt. 7 = 12x 10% NFA applied to water solution; and Trt. 8 = 9x 50% NFA. The experimental design was randomized complete block design with five replicates per treatment. PIX was first applied after the appearance of five to six nodes with subsequential application of PIX for those corresponding treatments beginning 72 h after previous application of PIX.

In the potted soil experiment, a subsurface drip system was installed 20 cm below the soil with three emitters per pot (4 L H_2O per hr), and a direct injection port for each pot. Three two-week old cotton seedlings were transplanted into 15 L pots containing Panoche clay loam (*Typic Torriorthents*). The experimental design structure was randomized complete block with six treatments, two block and four replicates per treatment. The treatments consisted of Trt. 1 = no Pix; Trt. 2 = 2x normal foliar application (NFA); Trt. 3 = 6x NFA applied to drip system; Trt. 4 = 12x 50% NFA applied to drip system; Trt. 5 = 12x NFA applied to drip system; Trt. 6 = 6x 50% NFA applied to drip system. Seven days after transplanting, each pot was reduced to the two healthiest seedlings. During the growth period, water was initially applied to simulate sprinkle irrigation. After plant establishment the PIX solution was injected directly into port injector of the drip system leading to each individual pot. A 0.25 modified Hoagland solution was also injected weekly through this port injector. The first PIX application began at the five true leaf stage. General growth observations noted for both experiments were height, number of nodes, internode distance, effect on tap, and fibrous root system.

<u>RESULTS</u>: Root applications of PIX can influence the morphological appearance of cotton, although the tested PIX concentrations induced milder changes than the foliar treatments (Table 1). As expected, the sprayed plants were shorter than the other treatments with fewer nodes and shorter internode distance in both plants grown in water culture or in potted soils. Although none of the root application treatments induced the same effects as the foliar application of PIX, those PIX root treatments with the highest concentrations and frequency rate, induced smaller scale changes in the cotton plant.

<u>FUTURE PLANS</u>: A field study will be conducted to evaluate the application of PIX in the subsurface drip system at different concentrations and at different frequency rates to two different cotton varieties.

Table 1. Effect of root applied PIX on cotton plants grown in water culture and potted soils.*

Water Culture**

Treatments	Height (cm)	Nodes #	Mean Internode Distance (cm)	Tap Root Length (cm)	Fibrous Root Length (cm)	Lack of Uniform Response
1 (no PIX)	90	18	8	21	25	no
2 (spray)	55	12	5	19	27	no
3	79	16	6	18	23	no
4	68	15	6	16	20	no
5	65	15	4	16	22	no
6	80	16	6	19	21	yes
7	82	17	7	20	25	yes
8	78	15	6	17	21	yes

Potted Soils***

Treatments	Height (cm)	Nodes #	Mean Internode Distance (cm)	Tap Root Length (cm)	Fibrous Root Length (cm)	Lack of Uniform Response
1 (no PIX)	66	14	5	NR	NR	no
2 (spray)	42	8	3	NR	NR	no
3	48	10	4	NR	NR	no
4	58	12	4	NR	NR	no
5	46	9	3	NR	NR	yes
6	55	11	4	NR	NR	no

* Values are presented as means from five replications per treatment per experiment, respectively.

NR No response; no visual differences observed; soil difficult to remove from roots.

** Trt. 1 = no application of PIX; Trt. 2 = Two times normal foliar application (NFA); Trt. 3 = One time NFA applied to water solution; Trt. 4 = Three times 50% NFA applied to water solution; Trt. 5 = Six times 50% NFA applied to water solution; Trt. 6 = Six times 20% NFA applied to water solution; Trt. 7 = Twelve times 10% NFA applied to water solution; Trt. 8 = Nine times 50% NFA applied to water solution.

*** Trt. 1 = no application of PIX; Trt. 2 = Two times normal foliar application (NFA); Trt. 3 = Six times NFA applied to drip system; Trt. 4 = Twelve times 50% NFA applied to drip system; Trt. 5 = Twelve times NFA applied to drip system; Trt. 6 = Six times 50% NFA applied to drip system.

LYSIMETER MEASUREMENTS OF EVAPOTRANSPIRATION IN MATURING PEACH TREES

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OBJECTIVES: To use a computerized weighing lysimeter system for determination of evapotranspiration of maturing peach trees and to control micro-irrigation systems in a real time feedback mode at several evapotranspiration rates in the research site surrounding the lysimeter. To produce a set of crop coefficient functions for years two through six for use with CIMIS to schedule irrigation of peaches in the San Joaquin Valley.

PROCEDURES: (For details about lysimeter design and instrumentation see 1986, through 1990 reports). The lysimeter (including the water in its irrigation tanks) was weighed hourly to determine the evapotranspiration (ET_c) of the two trees; the mass loss of the lysimeter was compared to a threshold mass of 96 kg (8 kg = 1 mm ET_c) and after 12 mm (96 kg) of ET_c was measured the lysimeter was irrigated until the threshold mass was met. At midnight each day, the water tanks were refilled to a pre-set level; the flow of water was measured electronically with a flowmeter and the new lysimeter mass was used as the baseline mass for the next day.

Daily, outputs from the lysimeters were transmitted automatically via telecommunication to the WMRL microcomputer and basic data were stored on a hard disk and backed up on high density floppy disks.

RESULTS: Table 1 shows monthly summaries of rainfall, lysimeter ET_c grass reference ET_0 (CIMIS), the lysimeter and actual tree crop coefficients (K_c's), and the number of lysimeter irrigations.

Figure 1 shows the daily reference ET_0 and the peach tree evapotranspiration calculated for the total area occupied by a tree (not the lysimeter area). Figure 2 shows the crop coefficients for nearly mature peach trees; the lysimeter calculated K_c is on the left axis and the actual tree K_c is on the right axis. Figure 3 shows the integrated crop coefficients for the tree from 1988 through 1991. These curves were generated by daily calculations of the cumulative ET_c and ET_0 data and taking the ratio of the slope of the ET_c and ET_0 curves. As discussed in previous reports the K_c tracks evapotranspiration and hence its accuracy in predicting ET_c is limited to $\pm$ 10%, especially on a daily basis. Each tree used approximately 8544 L of water. Reference ET_0 was 1358 mm. There were 163 irrigations, totaling 1956 mm of applied water and 298 mm of rainfall. No drainage was collected from the lysimeter. The two trees in the lysimeter grew to a size approximately equal to the size of the trees in the surrounding orchard.

FUTURE PLANS: This experiment will be continued until the peach trees reach a fully mature stage.

Month	Rain (mm)	ETc Lysimeter (mm)	Cimis (ETo) (mm)	Lysimeter Kc	Actual Kc (8.91 m2 /tree)	# of lysimeter Irrigations
Jan	4	9	36			0
Feb	26	10	58			0
March	202	47	66	0.72	0.32	0
Apr	4	110	147	0.75	0 .34	7
May	1	238	172	1.38	0.62	21
Jun	0	322	188	1.71	0.77	27
Jul	0	433	207	2.09	0.94	36
Aug	0	392	166	2.35	1.06	33
Sep	0	309	132	2.35	1.06	26
Oct	16	232	94	2.47	1.11	13
Nov	5	33	56			0
Dec	40	2	35			0
Total	298	2136	1358			163

Table 1. Monthly totals of rainfall, peach tree ET_c (lysimeter), reference ET (ET_o, CIMIS) lysimeter and peach tree K_c's, and number of irrigations.

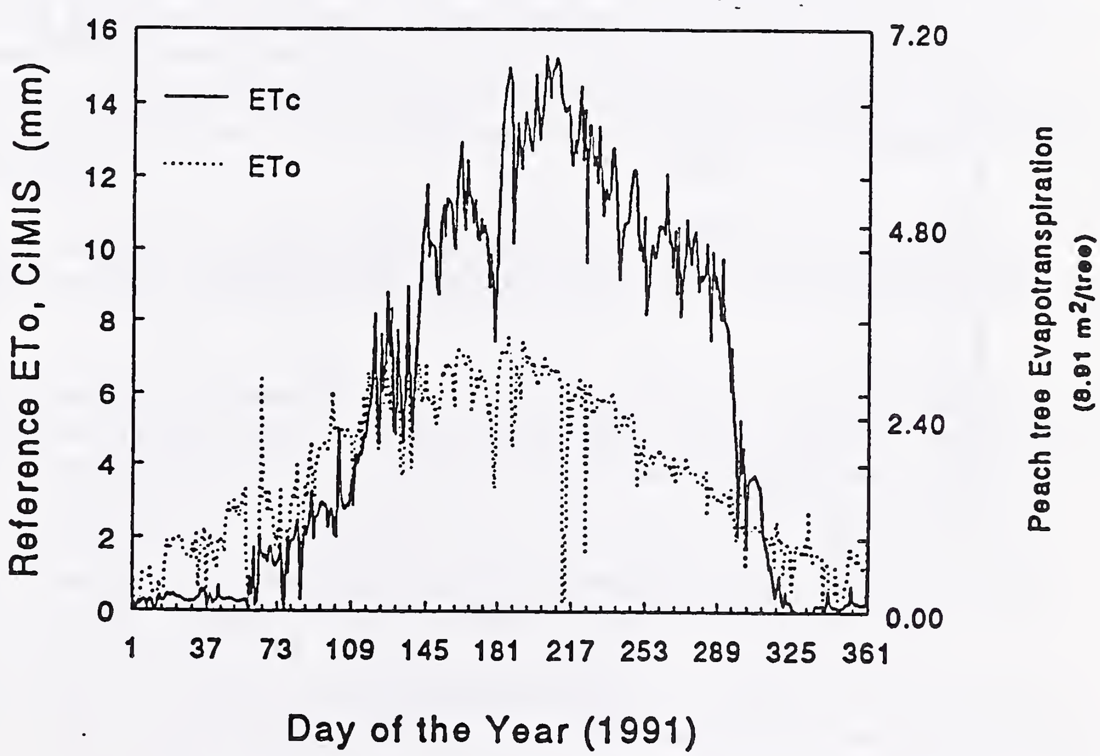


Figure 1. Daily reference ET (ET_o, CIMIS) (left axis) and daily peach tree evapotranspiration (8.91 m^2/tree) (right axis) for nearly mature peach trees.

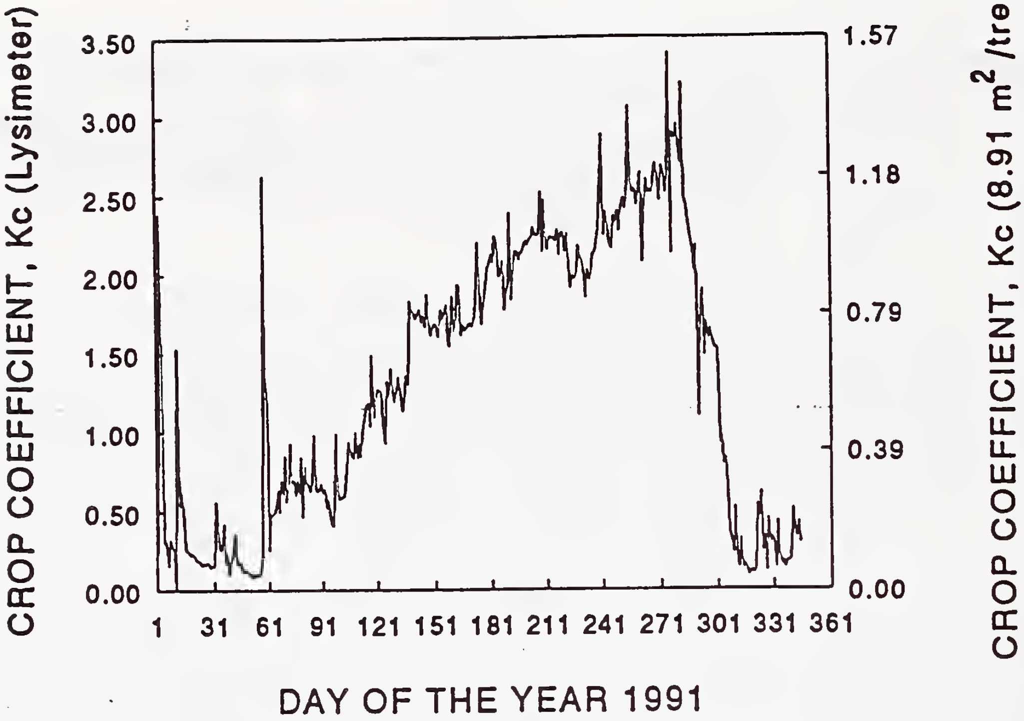


Figure 2. Crop coefficients of nearly mature peach trees based on lysimeter area (left axis) and actual area occupied by each peach tree (right axis).

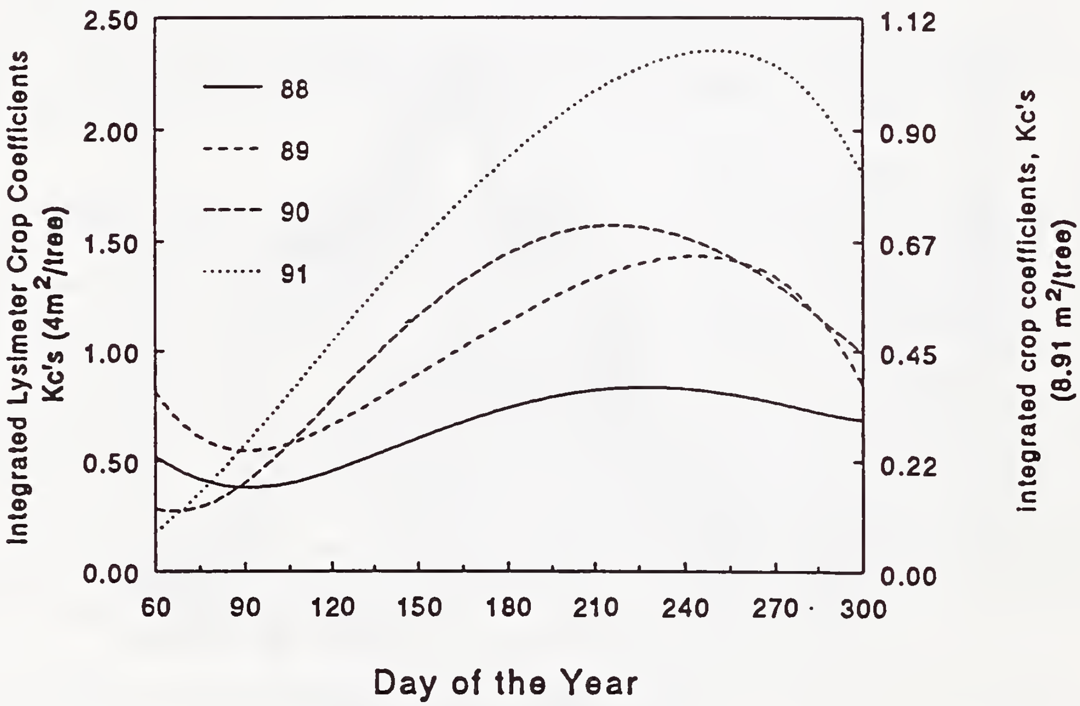


Figure 3. Integrated crop coefficients K_c's for nearly mature peach trees planted in 1987 (lysimeter area, left axis and actual area, right axis).

LYSIMETER MEASUREMENTS OF EVAPOTRANSPIRATION IN MATURING GRAPES

C.J. Phene, L. Williams, D. Clark, R.M. Mead, P. Biscay, and D. Grimes

OBJECTIVES: To use a computerized weighing lysimeter system for determination of evapotranspiration, crop coefficient (K_c) and soil matric potential of drip irrigated grapes; to control in a real time feedback mode surface and subsurface drip systems at several evapotranspiration rates in the research site surrounding the lysimeter; to produce a set of crop coefficient functions for years two through six for use with CIMIS to schedule irrigation of grapes in the San Joaquin Valley.

PROCEDURES: The lysimeter (see 1987 through 1990 annual reports for details), including the water in the tanks, was weighted hourly to determine the evapotranspiration (ET_c) of two grape vines; the mass change was compared to a threshold mass of 16 kg (8 kg - 1 mm ET_c) and after 16 kg of mass loss the lysimeter was irrigated until the threshold mass was met. At midnight each day the water tanks were refilled to a pre-set level, the volume of water was measured with an electronic flowmeter and the lysimeter mass was used as the baseline mass for the next day. Daily crop coefficients (K_c) were calculated by taking the ratio of ET_c/ET_0 where ET_0 is the grass reference evapotranspiration. Reference crop ET (ET_0) was calculated from data collected at a CIMIS weather station located at the Kearney Ag Center, approximately 325 m from the Thompson Seedless vineyard used in this study. Soil water content was measured with a Troxler Model 3332 Depth Moisture Gauge (neutron probe). Two access tubes are placed within the lysimeter's soil contained and sets of nine access tubes are placed throughout the vineyard. The distribution of the nine access tubes at each location resulted in the measurement of soil water in one quarter of the vine roots' soil volume. Daily sensor outputs from the lysimeter were transmitted via telecommunication to the WMRL microcomputer and basic data were stored on a hard disk and backed up on high density floppy disks.

RESULTS: Table 1 shows monthly summaries of rainfall, lysimeter ET_c, the reference evapotranspiration (ET_0), the lysimeter K_c, the actual vine K_c and the number of lysimeter irrigations.

Figure 1 shows the daily reference ET_0 and the vine evapotranspiration calculated for the total area occupied by a vine (not the lysimeter area). Figure 2 shows the crop coefficients for mature Thompson seedless vines; the lysimeter calculated K_c is on the left axis and the actual vine K_c is on the right axis. Figure 3 shows the integrated crop coefficients for the vines from 1988 through 1991. These curves were generated by daily calculations of the cumulative ET_c and ET_0 data and taking the ratio of the slope of the ET_c and ET_0 curves. As discussed in previous reports, the K_c tracks evapotranspiration and hence its accuracy in predicting ET_c is limited to $\pm$ 10%, especially on a daily basis. Each vine used approximately 6812 L of water. Reference ET_0 was 1358 mm. There were 767 irrigations, totaling 1534 mm of applied water and 298 mm of rainfall. No drainage was collected from the lysimeter, The two vines in the lysimeter grew to a size approximately equal to the size of the vines in the surrounding vineyard.

FUTURE PLANTS: This experiment will be continued until the vines reach a fully mature stage.

Month	Rain (mm)	ETc Lysimeter (mm)	Cimis (ETo) (mm)	Lysimeter Kc	Actual Kc (7.52 m^2 /vine)	# of lysimeter Irrigations
Jan	4	9	36			0
Feb	26	14	58			0
March	202	55	66	0 .83	0 .44	0
Apr	4	51	147	0 .35	0 .19	10
May	1	139	172	0.81	0 .43	61
Jun	0	281	188	1.5	0 .8	141
Jul	0	355	207	1.72	0..92	177
Aug	0	327	166	1.96	1.04	164
Sep	0	260	132	1.97	1.05	135
Oct	16	165	94	1.76	0 .94	77
Nov	5	37	56			0
Dec	50	10	37			2
Total	298	1703	1358			767

Table 1. Monthly totals of rainfall, grapevine ET_c (lysimeter), reference ET (ET_o, CIMIS), lysimeter and grapevine K_c's, and number of irrigations.

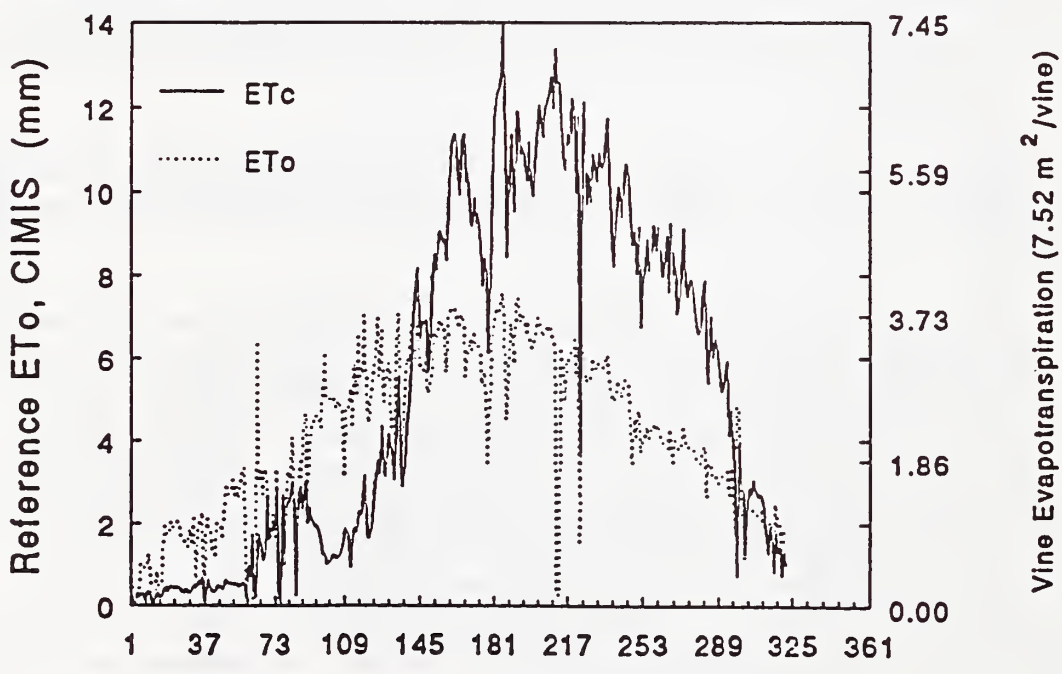


Figure 1. Daily reference ET (ET_o, CIMIS) (left axis) and daily vine evapotranspiration (7.52 m^2/vine) (right axis) for nearly mature Thompson Seedless vines.

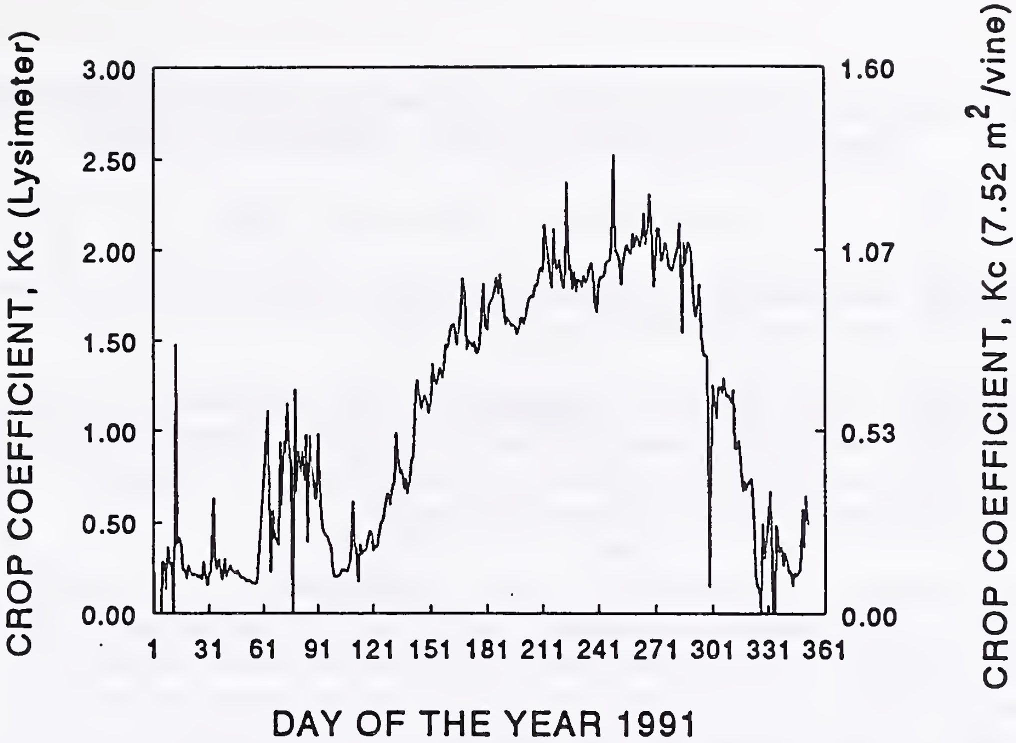


Figure 2. Crop coefficient of nearly mature Thompson Seedless vines based on lysimeter area (left axis) and actual area occupied by each grapevine (right axis).

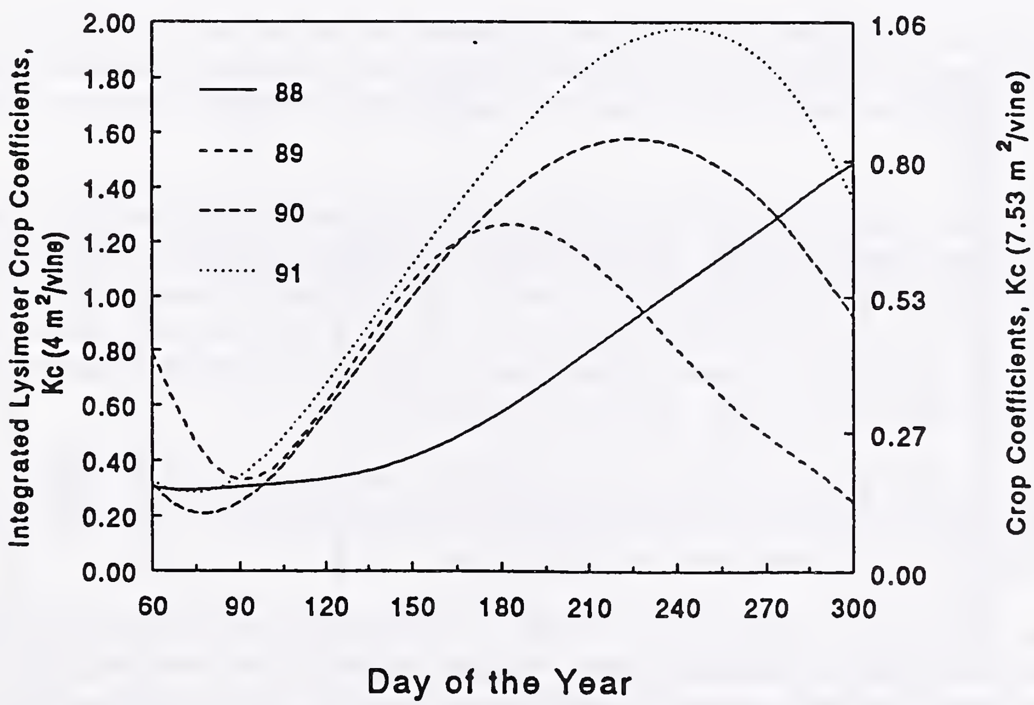


Figure 3. Integrated crop coefficients K_c's for maturing Thompson Seedless vines planted in 1987 (lysimeter area, left axis and actual area, right axis).

REAL-TIME IRRIGATION CONTROL SYSTEM FOR ROW-CROP SUBSURFACE DRIP EVALUATION PROJECT - IMPERIAL VALLEY

G.E. Cardon, D.A. Clark, and C.J. Phene

OBJECTIVES: To implement an irrigation control system based on actual crop water use determined from real-time soil moisture measurements.

PROCEDURES: Twenty soil matric potential sensors (heat dissipation type, Model AGWA-III, Agwatronics, Merced, CA) were calibrated according to the methodology described in the section of this report entitled "Calibration of Soil Matric Potential Sensors: Physical Equipment and Statistical Data Processing Methodology".

The sensors were then installed in field F3 at the Irrigated Desert Research Station in Brawley, CA. Five Sensors were installed in each of the four replications of irrigation treatment 3 [100% of crop evapotranspiration (ET_c)] as illustrated in Figures 1 and 2 (for a more complete description of the field and treatments for this experiment refer to the section of this report entitled: "Subsurface Drip Evaluation - Imperial Valley"). Each set of sensors is connected to a separate data logger powered by a solar panel (Model CR1O, Campbell Scientific, Inc., Logan, Utah). Each data logger is then connected in series to a master logger at the edge of the field using the special SDI communication software of Campbell Scientific (Logan, Utah). Hourly measurements of soil temperature and matric potential from the twenty sensors and the panel temperature and battery voltage for each field data logger are downloaded from the master logger each day via telephone modem at WMRL in Fresno, CA.

Hourly averages of soil temperature and matric potential for each of the four 100% ET_c plots and for the entire field are calculated from this data and plotted by an automated report generating program on the WMRL computers. Example daily reports are shown as Figures 3 and 4.

The master data logger is programmed to initiate irrigation when the field-averaged matric potential reaches a threshold value. Upon initiation of irrigation, Treatment 3 (100% ET_c) operates for 40 minutes (approximately 0.75 mm of applied irrigation water), the other 3 treatments run for a multiple of that amount of time. Every hour on the hour, the master logger averages the field's soil matric potential and will continue to initiate irrigations every hour until the matric potential rises above the set threshold value.

RESULTS: Applied irrigation water can be adjusted by varying the threshold level as a real-time feedback control system or to meet estimated ET_c levels calculated from weather data, evaporation pan data, lysimeter data, or other method.

A summary of applied irrigation water on cotton vs. estimated ET_c based on Brawley pan evaporation data (Epan) is given as Figure 5. Differences between the two curves may be due to error in the coefficients used to convert Epan data to ET_c, and to field conditions (soil moisture variability, pest pressure, soil fertility, etc.) that can alter crop water use. Neutron

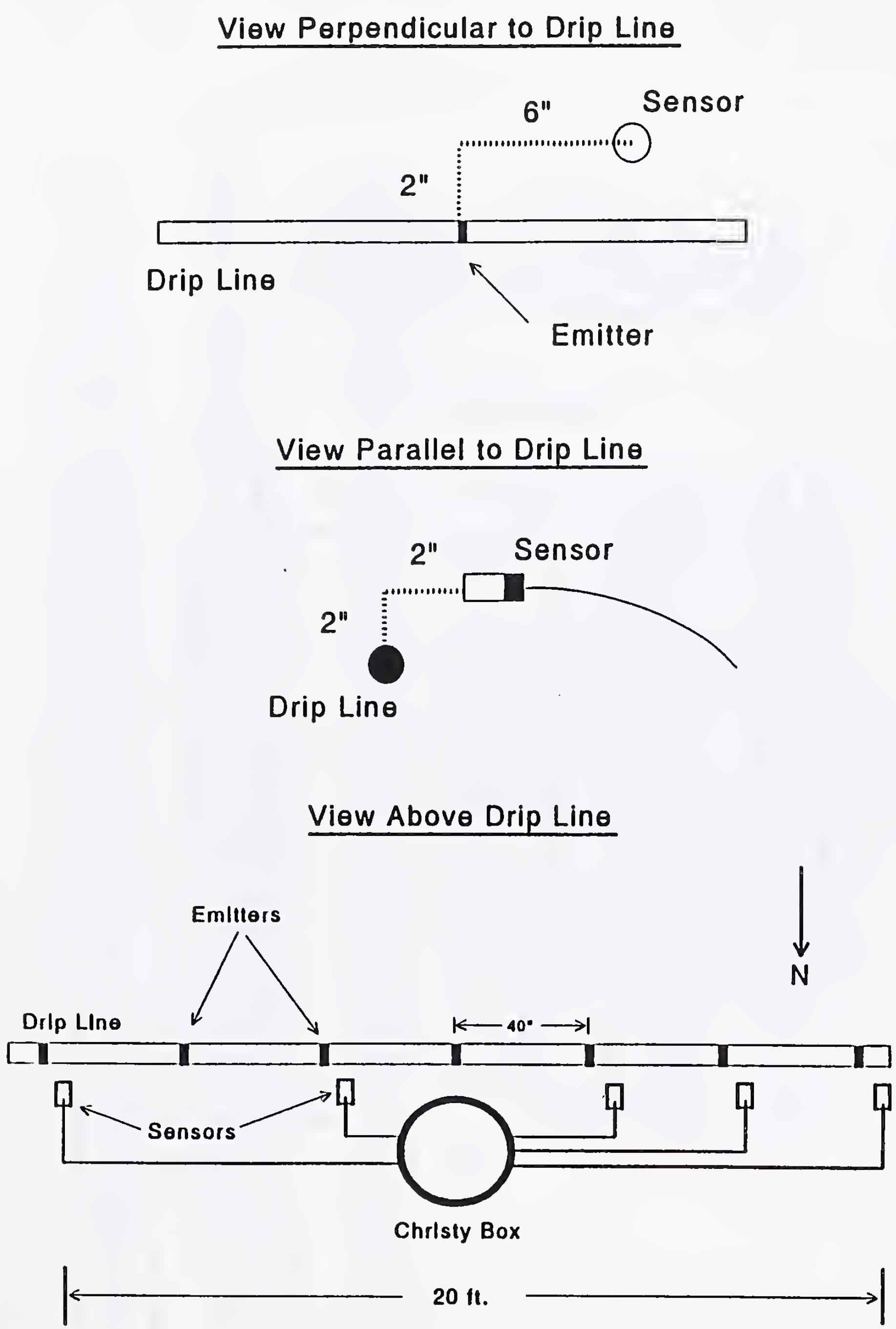


Figure 1

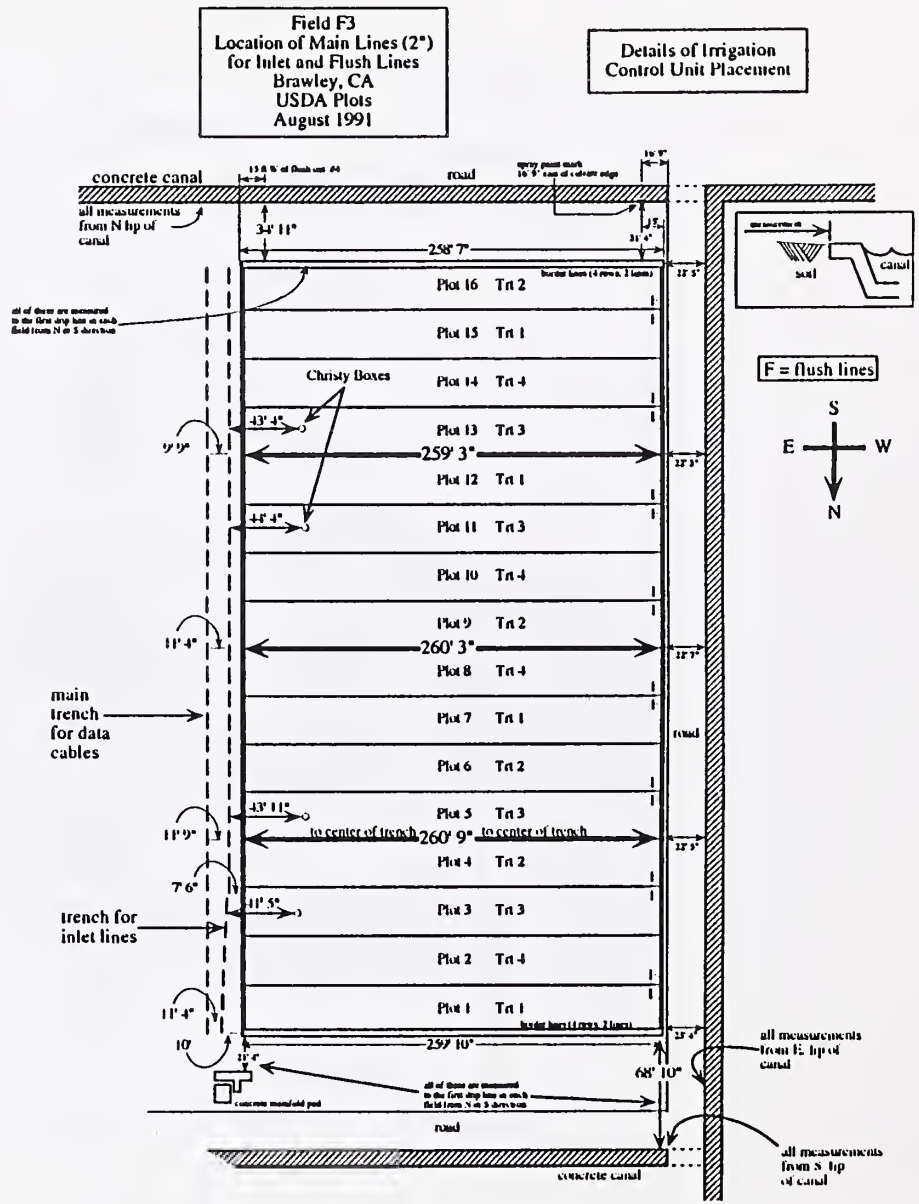


Figure 2

BRAWLEY SMPS Date: 7/15/92 Julian Day: 197

Threshold (Bars): -0.150

	Max	Min
Battery (V):	13.29	12.65
Temperature (°C):	33.29	22.43

Time (hr-min)	Ave. SMP (Bars)	Irri. Flag	Error Code
100	-0.180	1	0
200	-0.169	1	0
300	-0.163	1	0
400	-0.172	1	0
500	-0.151	1	0
600	-0.165	1	0
700	-0.159	1	0
800	-0.148	0	0
900	-0.142	0	0
1000	-0.139	0	0
1100	-0.149	0	0
1200	-0.169	1	0
1300	-0.185	1	0
1400	-0.175	1	0
1500	-0.159	1	0
1600	-0.157	1	0
1700	-0.158	1	0
1800	-0.140	0	0
1900	-0.138	0	0
2000	-0.167	1	0
2100	-0.178	1	0
2200	-0.148	0	0
2300	-0.158	1	0
2400	-0.158	1	0
	Ave. SMP (Bars)	Irri. (#)	
Daily:	-0.159	17	

Sensor Number	Ave. SMP (Bars)	SMP CV (%)	Ave. Temp. (°C)	Temp. CV (%)
1.1	-0.257	5.8	27.5	0.4
1.2	-0.106	17.1	27.5	0.6
1.3	0.032	47.2	27.3	0.5
1.4	-0.208	8.5	27.2	0.4
1.5	-0.230	10.8	27.2	0.4
#1 Ave:	-0.140	20.2	27.4	0.5
2.1	-0.178	17.4	27.4	0.4
2.2	-0.344	7.8	27.2	0.3
2.3	-0.103	28.0	27.4	0.5
2.4	-0.305	0.1	27.1	0.4
2.5	-0.384	9.2	27.4	0.5
#2 Ave:	-0.195	14.5	27.3	0.4
3.1	0.037	64.0	27.5	0.7
3.2	-0.179	9.8	27.3	0.8
3.3	0.004	759.8	27.3	0.5
3.4	-0.469	4.9	27.4	0.8
3.5	-0.118	22.1	27.3	0.6
#3 Ave:	-0.145	172.1	27.4	0.8
4.1	-0.214	9.3	27.3	0.5
4.2	-0.454	11.0	27.1	0.4
4.3	-0.151	26.2	27.1	0.6
4.4	-0.008	347.6	27.3	0.8
4.5	-0.306	6.7	27.3	0.4
#4 Ave:	-0.170	97.4	27.2	0.5
	Ave. SMP (Bars)	Ave. CV (%)	Ave. Temp. (°C)	Ave. CV (%)
Active Sensors:	-0.159	85.9	27.3	0.5

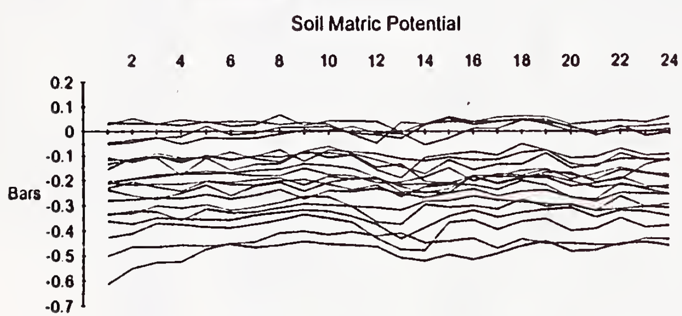


Figure 3

BRAWLEY SMPS Date: 7/15/92 Julian Day: 197

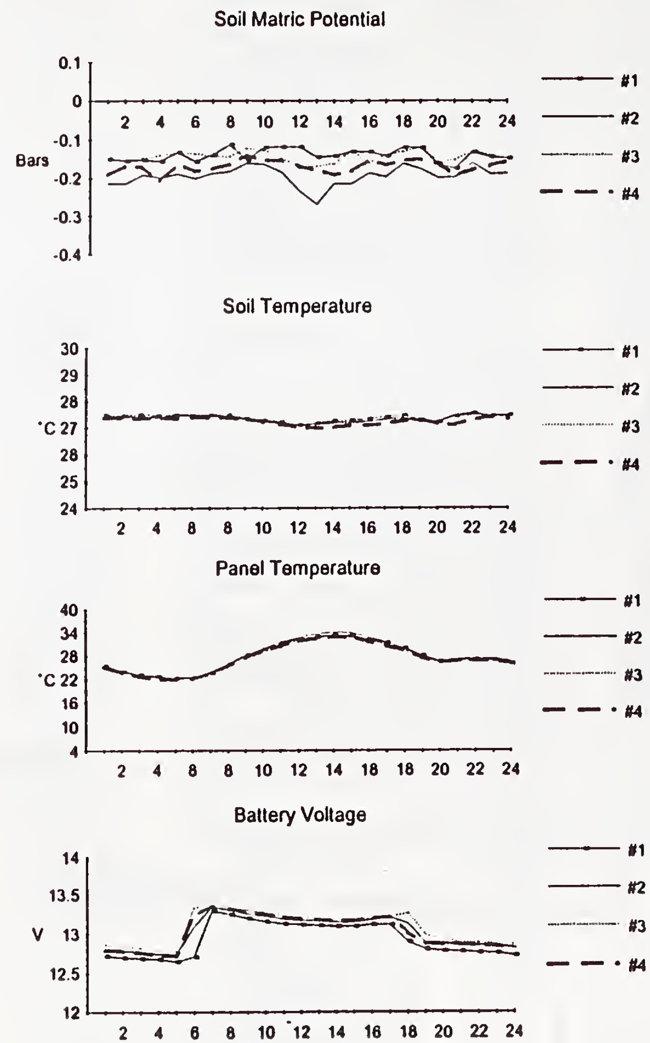


Figure 4

probe data taken since the initiation of control by the described system shows that only very small changes in soil moisture are occurring, suggesting that applied water is following crop water use very closely.

<u>CONCLUSIONS</u>: This is the first season that the system has been installed and everything is functioning properly. Applied irrigation water is keeping pace with the crop water requirement as evidence by neutron probe data.

<u>FUTURE PLANS</u>: We will continue to use the system, including the development of ET_c curves for future crops based on data of soil matric potential, neutron probe depletion, and applied water.

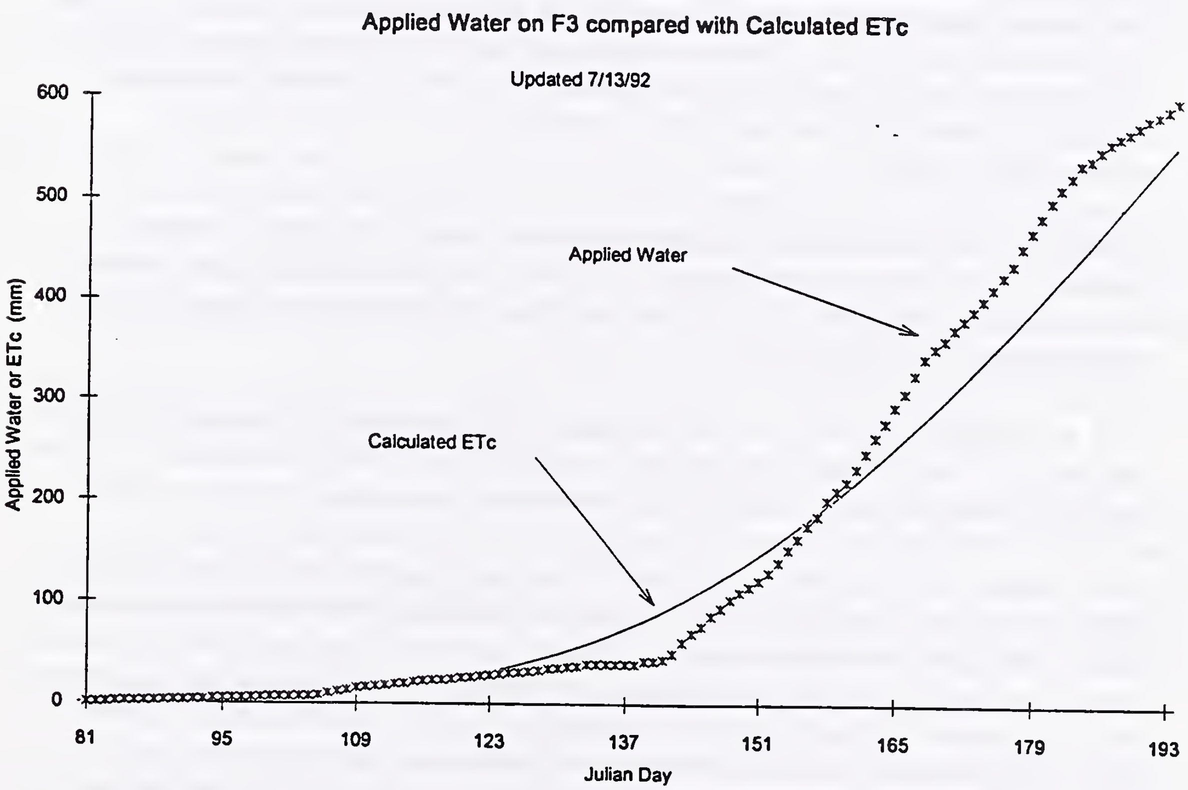


Figure 5

CALIBRATION OF SOIL MATRIC POTENTIAL SENSORS: PHYSICAL EQUIPMENT AND STATISTICAL DATA PROCESSING METHODOLOGY

G.E. Cardon, C.J. Phene, D.A. Clark and F. Piyasil

OBJECTIVES: To develop a standardized calibration procedure with well defined, statistically based guidelines for data monitoring and processing that will ensure maximum calibration accuracy and consistency.

METHODS: Environmental control plays a key role in calibration accuracy. Temperature and pressure must be regulated carefully, and monitored regularly to obtain the best results. A successful temperature and pressure control system which we recommend is illustrated in Figure 1. Following is a step-by-step outline of the proposed calibration methodology.

CALIBRATION STEPS

1. Prepare the calibration medium by combining 75% soil (passing a 0.2 mm sieve) with 25% diatomaceous earth. The soil fraction should be taken from a source low in smectite clays to prevent cracks forming in the medium due to the shrinking of the clay lattice during drying. This mixture provides good water holding capacity over a wide range of matric potential, forms good contact with the sensor ceramic and ceramic extractor plate, and has good hydraulic conductivity characteristics (reasonable rapid flow).

2. Thoroughly wet the ceramic extractor plate in tap water, and place in pressure chamber. Once placed in the pressure chamber, the plate should be kept moist to ensure that it is saturated. This will ensure that air will not pass through the plate when pressure is applied later.

3. Pack some calibration medium that has been partially wetted, into the retainer ring, and on top of the ceramic extractor plate, halfway up the ring. Make sure that good contact is made between the calibration medium and the ceramic extractor plate.

4. Insert sensor cables in the slits of the PVC retainer ring and out through the strain-relief connectors. Firmly, but gently, press the sensors into the calibration medium. Pack some of the remaining medium on top of each individual sensor as it is placed into the calibration medium. This will keep the sensor in place and help in forming the all-important contact between the calibration medium and the sensor ceramic. Once all the sensors have been inserted, pack the remaining partially wetted calibration medium into the retainer ring. Be sure that the packing is done radially outward from the center of the ring, all the way tot he wall of the ring. This will ensure complete packing and will help prevent shifts in the medium when under pressure.

5. Wet the entire calibration medium-sensor-extractor plate unit by keeping the ceramic extractor plate wet around the outside of the retainer ring. This will ensure that entrapment of air in the calibration medium will be minimized. While the assembly is wetting, keep the lid loosely placed on the pressure chamber to limit evaporation.

6. Once the calibration medium is saturated, tighten the pressure chamber lid and apply 0.05 MPa of pressure to the system for 12 hours. This will help settle the calibration medium.

7. Repack the calibration medium to remove any cracks formed during settling. Re-wet the medium and sensors again via the ceramic extractor plate. Repeat steps 6 and 7 a second time.

8. After a third re-wetting, the system should be sufficiently settled to begin calibration. Close and tighten the lid of the pressure chamber and place the entire assembly in a constant temperature chamber like the one diagrammed in Figure 1. Allow 24-48 hours for the system to come to temperature equilibrium.

9. Raise the pressure to the lowest desired calibration pressure. Be sure the outflow tube from the pressure plate is not constricted and that the outflow collection vessel is at the same level as the ceramic extractor plate within the pressure plate apparatus so that no net gravitational or head gradient is imposed on the flow of water out of the calibration system.

10. Check for air leaks from the pressure chamber along the lid and around the interfaces of the strain-relief connectors with the sensor cables and the wall of the pressure chamber. Leaks should also be checked for around any other device or port in the wall of the pressure chamber. The easiest way to detect leaks is with a diluted soap solution squirted onto the points of interest. If any bubbles form, release the pressure and seal the leak area. One should check for leaks periodically throughout the calibration process, particularly at each new level of applied pressure. Air leaks are one of the most significant error-causing problems in calibration.

11. If there are no leaks then begin taking measurements. Review the data collected each day. Hourly measurements of the post-heating temperature rise (ΔT) of each sensor are recommended in order to allow the heat pulse applied to each sensor to be fully dissipated by the next measurement period. Daily monitoring of the data is important in detecting possible problems with the sensors or other components of the calibration system. Potential problems are reviewed in the next section of this paper.

12. When water outflow from the pressure chamber has visibly ceased, begin linear regression checks on the ΔT data of each sensor over (at least) the most recent 25 points. This will provide a solid statistical basis for equilibrium determination.

13. When the regression analysis results in a slope of zero (to 2 decimal places) and a coefficient of determination less than 0.10 (for each sensor being calibrated) then raise the pressure to the next desired calibration pressure and repeat steps 11 and 12.

14. After calibration has been performed over the entire range of desired pressure, then a final regression analysis on the observed means of the ΔT of each sensor at each calibration pressure level, can then be performed to determine the best fit (linear, quadratic, etc.) for the final calibration equation.

RESULTS: The calibration data generated using the above method for a single sensor is given in Figure 2. The results of the statistical data processing methodology is given in Table 1 for the three sections of data indicated in Figure 2. The final calibration curve from the data in Figure 2 is presented in Figure 3. Note that two options for the final calibration curve are given. For most applications (irrigation control, soil moisture monitoring, etc.) the linear calibration curve provides sufficient information over the data range. For applications that require finer resolution (evaporation or other flow studies) the quantification of calibration error provided by the proposed method is important. Figure 3 illustrates that a quadratic calibration curve provides statistically significant information for this sensor based on the level of error associated with these data.

CONCLUSIONS: With the proposed methodology, the many possible sources of error in the calibration of soil matric potential sensors can be quantified and controlled within the limits of accuracy of the calibration system components (in this case, ±0.001 MPa for pressure and ±0.12 C for temperature). Moreover, the method provides a statistically objective definition for "equilibrium" between the sensor measurements and calibration pressure, which leads to accurate and reproducible calibration results.

Table 1. Linear regression results of post-heated temperature rise (ΔT) vs. time over indicated time intervals from Figure 2.

Time Intervals (hrs.)	# of points	Slope of regression	Mean ΔT	St. dev.	R^2
340 to 389	50	0.0008	7.15	0.016	0.62
390 to 439	50	0.0003	7.17	0.011	0.16
440 to 479	40	0.0001	7.18	0.009	0.04

FUTURE PLANTS: A manuscript is currently in peer review for eventual submission to the Journal of Applied Engineering in Agriculture, ASAE.

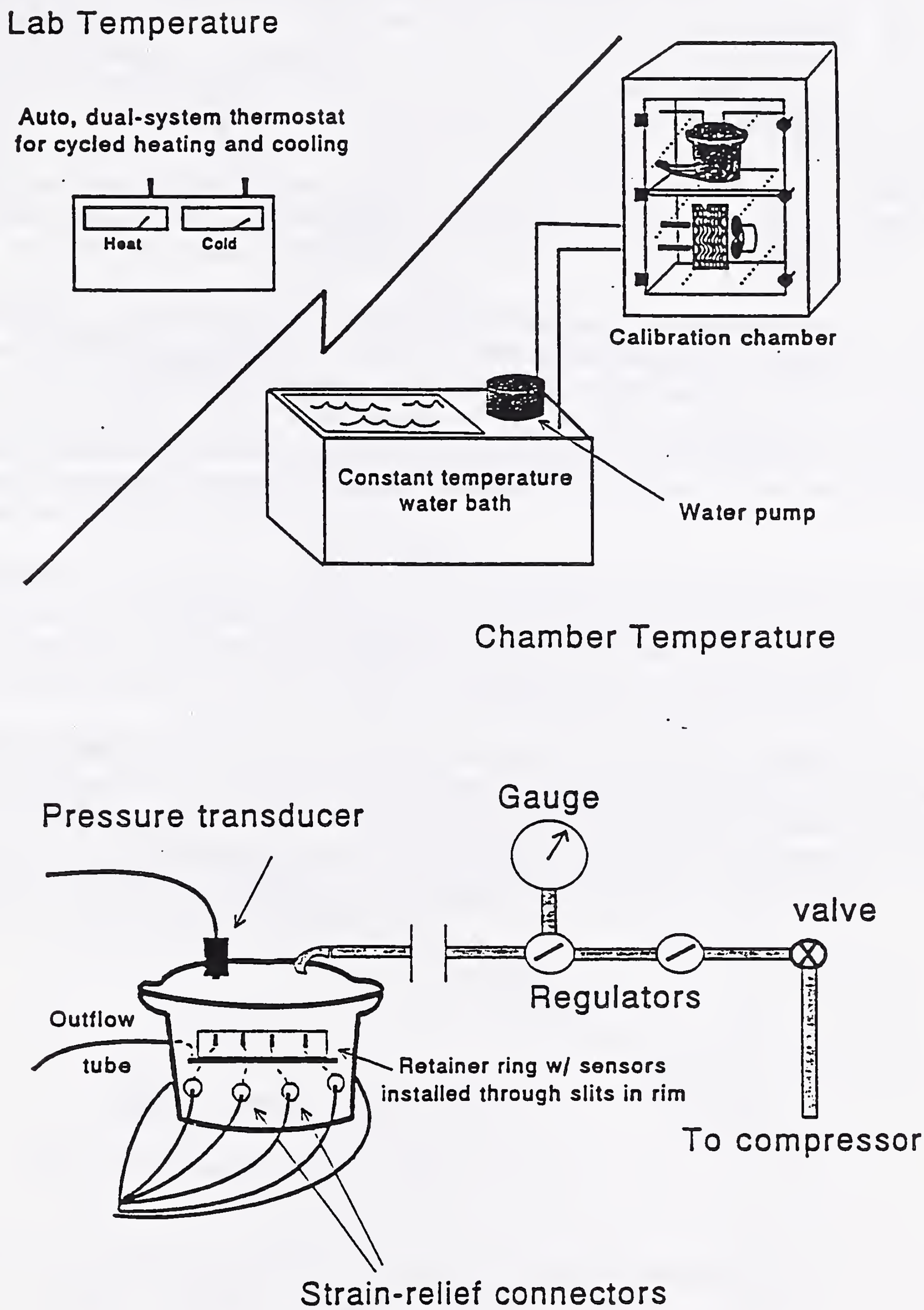
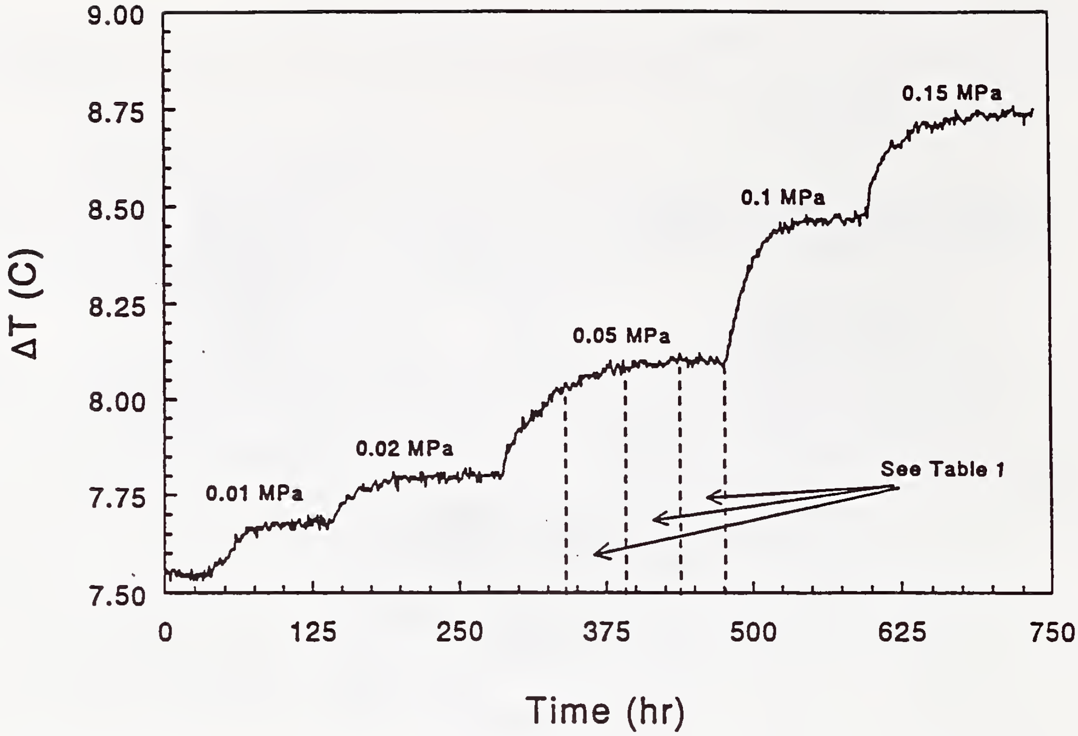
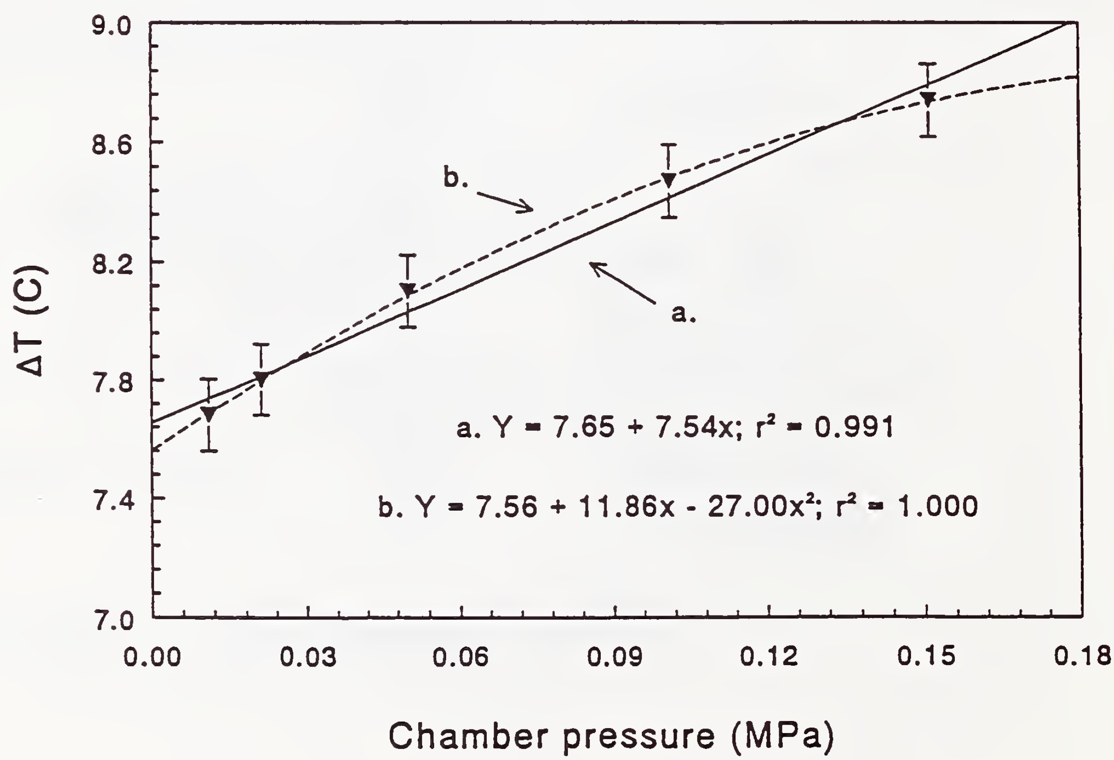

Lab Temperature
Auto, dual-system thermostat for cycled heating and cooling
Heat
Cold
Calibration chamber
Constant temperature water bath
Water pump
Chamber Temperature
Pressure transducer
Gauge
valve
Regulators
Outflow tube
Retainer ring w/ sensors installed through slits in rim
To compressor
Strain-relief connectors

Fig 1.



9.00
8.75
8.50
8.25
8.00
7.75
7.50
ΔT (C)
0.15 MPa
0.1 MPa
0.05 MPa
0.02 MPa
0.01 MPa
See Table 1
0
125
250
375
500
625
750
Time (hr)

Fig 2.



9.0
8.6
8.2
7.8
7.4
7.0
ΔT (C)
b.
a.
a. Y = 7.65 + 7.54x; r² = 0.991
b. Y = 7.56 + 11.86x - 27.00x²; r² = 1.000
0.00
0.03
0.06
0.09
0.12
0.15
0.18
Chamber pressure (MPa)

Fig 3.

<u>RESULTS</u>:
EXPERIMENT 1: Figure 1 illustrates the diurnal fluctuation in the water level in the evaporation pan when evaporation is prevented from occurring. The dashed line represents the level that the water was originally set to prior to the start of the experiment. The net difference in the measured water level (the sum of the original set level minus each measured level) is zero indicating that no water was lost to evaporation and that all changes observed were due to changes in the systems "apparent" volume. The "apparent" volume changes reflect pan and water expansion and contraction due to heating and cooling. Water density fluctuations calculated from measured water temperature are subtracted out from the data in Figure 1 to reveal water level changes caused by pan volume fluctuations (Figure 2).

EXPERIMENT 2: Simultaneous pan weight and water level measurements for a two day period are summarized in Figure 3. The water level measurements show the same response as that for the previous test (oil covered water) where apparent sudden losses and gains of water are seen at 1830 hr and 0930 hr on each of the two days summarized in this figure. These are approximately the same intervals and times noted in the discussion of Figure 1. Moreover, a time-lag of four to five hours is seen between the onset of the peak evaporation rates measured by the scale and level sensor.

EXPERIMENT 3: A graphical comparison of the cumulative evaporation data for the two pan refill times previously mentioned, is given as Figure 4. Note that for the 0600 hr fill time, high "apparent" evaporation occurs through the night hours well after midnight. The measurements taken after the 1400 hr refill do not exhibit the same phenomenon.

<u>FUTURE PLANS</u>: Further study will be made to quantify the heat and mass balance of the evaporation pan system as a whole, along with more detailed characterization of the changes which the metal pan itself undergoes during diurnal heating and cooling. The data will be used to model the dynamics of automated evaporation pan systems to obtain accurate real time sub-daily evaporation estimates. A manuscript is being prepared for eventual submission to a peer-reviewed journal.

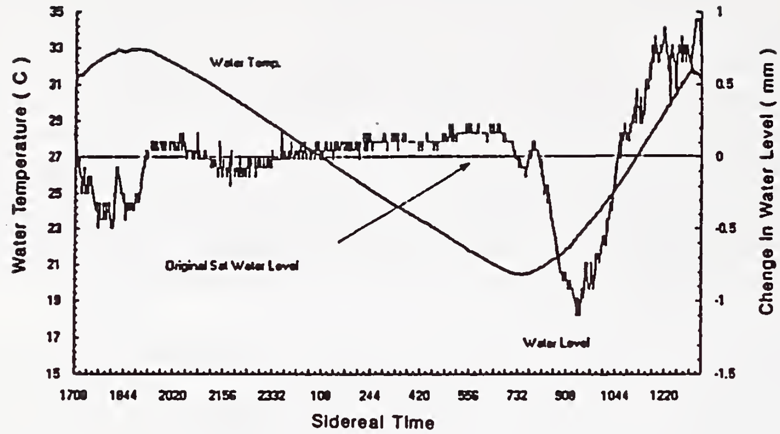


Fig 1.

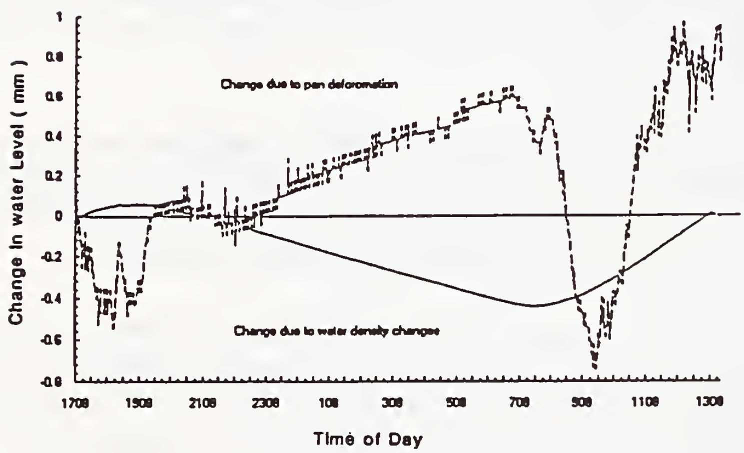


Fig 2.

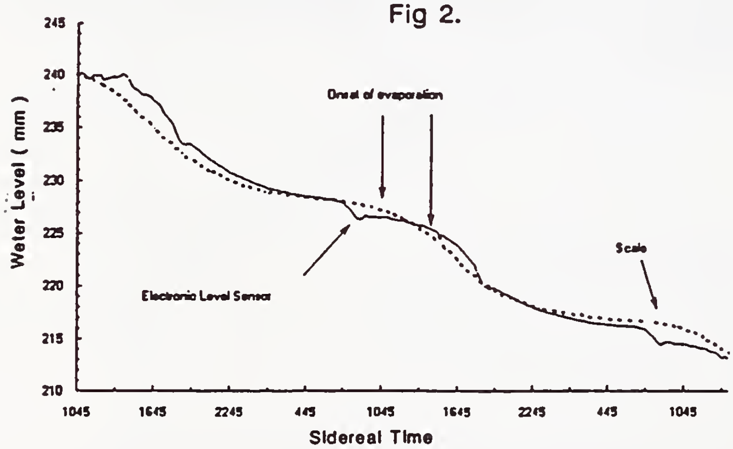
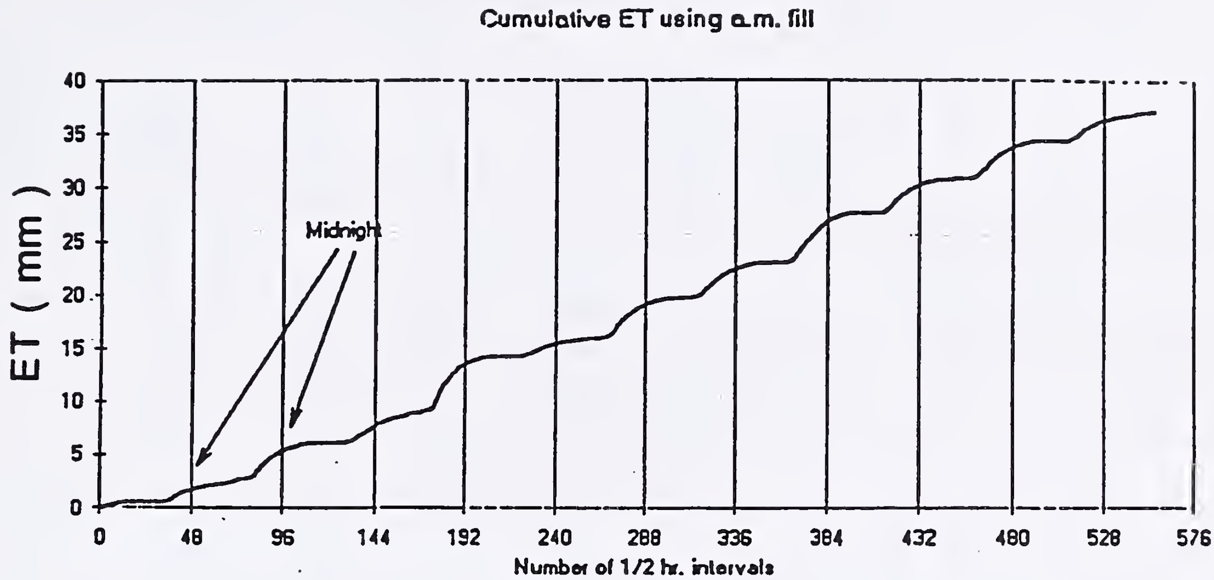


Fig 3.


Cumulative ET using a.m. fill
ET (mm)
Midnight
0
5
10
15
20
25
30
35
40
0
48
96
144
192
240
288
336
384
432
480
528
576
Number of 1/2 hr. intervals

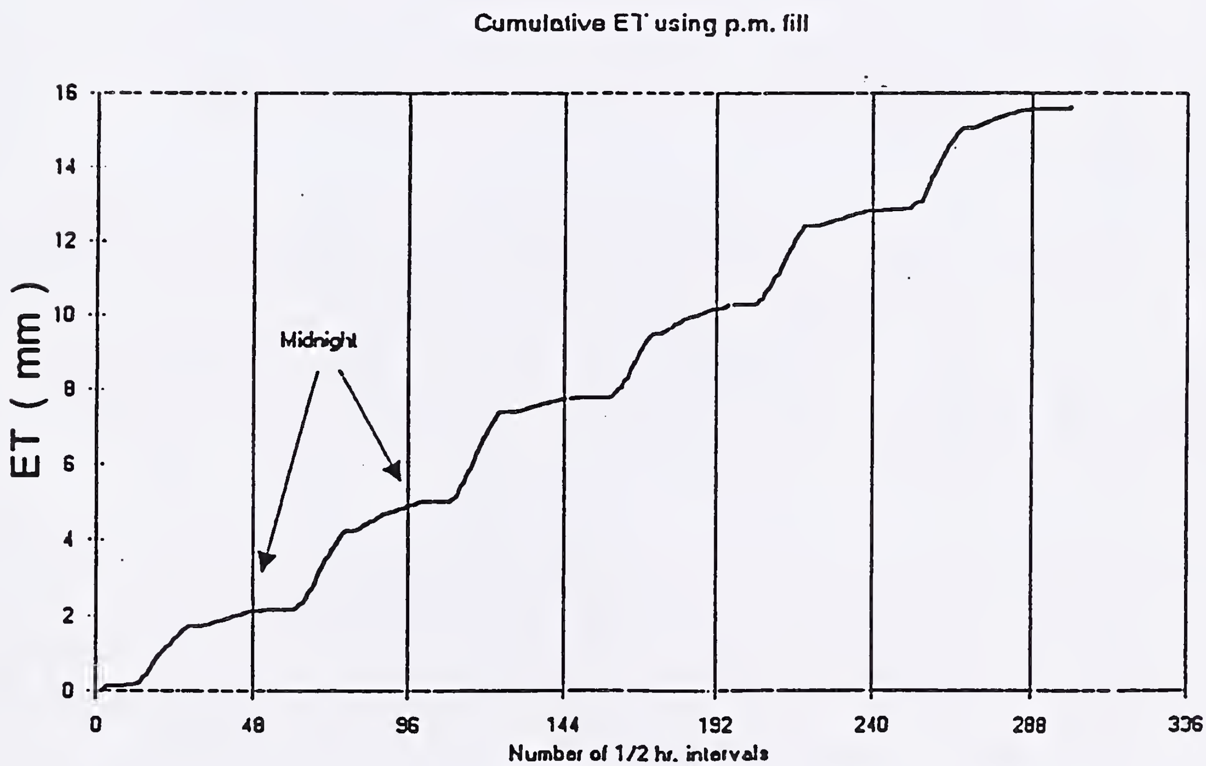

Cumulative ET using p.m. fill
ET (mm)
Midnight
0
2
4
6
8
10
12
14
16
0
48
96
144
192
240
288
336
Number of 1/2 hr. intervals

Fig. 4

CHARACTERIZATION OF THE SUB-DAILY DYNAMICS OF AN AUTOMATED CLASS-A EVAPORATION PAN

G.E. Cardon, C.J. Phene, F. Piyasil, and D.A. Clark

OBJECTIVES: To characterize the dynamics of sub-daily evaporation measurements from an automated class-A evaporation pan.

PROCEDURES: A class-A evaporation pan (Epan) was installed on the WMRL site. The water level in the pan was monitored by an electronic level sensor (Model MN-2, BCP Electronics, Clovis, CA) read by a micro data logger (Model 21X, Campbell Scientific Inc., Logan, UT). The data logger was programmed to open a solenoid valve and refill the pan at a preset threshold water level. Three initial experiments were conducted to characterize the response of sub-daily evaporation measurements recorded using the electronic water level sensor during complete diurnal cycles.

EXPERIMENT 1: Previous experience with automated evaporation pans has indicated that sub-daily measurements may be affected by changes in the water volume or the metal pan dimensions caused by diurnal heating and cooling. To better understand this phenomenon, a layer of clear mineral oil was floated on the surface of the water. This oil layer prevented evaporation, allowing measurement of the magnitude of daily changes associated with the various components of the system. In addition, simultaneous measurement of the water temperature was done in four locations within the pan. The average temperature from these measurements allowed calculation of the expected volume change of water with diurnal temperature fluctuation.

EXPERIMENT 2: The entire evaporation pan assembly was placed on top of a platform scale (Model KC240 interfaced with the ID2 Multirange terminal, Mettler Instrument Corp., Hightstown, NJ) and simultaneous measurements of pan weight loss and water level were recorded. The resolution of the scale measurements was 0.002 kg (NBS handbook 44 high accuracy class II). This experiment allowed the quantification of the temporal phase-shift in the Epan level measurements due to pan volume or water density variations, and a direct comparison between evaporation calculated from the level sensor readings and actual evaporation as measured by the scale.

EXPERIMENT 3: It was desirable to characterize the effect of the time of day at which the pan was refilled since the temperature of the water at refill will affect the density of the water and indirectly, the pan dimensions. Measurements were recorded for fill times at the coldest point of the day ($\approx$ 0600 hr) and hottest point of the day ($\approx$ 1400 hr) as determined by air temperature. The effect of fill-time on half-hourly measurements of water level and the resulting cumulative evaporation curves for the two fill times was investigated.

THE POTENTIAL OF NON-NATIVE SELENIUM ACCUMULATING MUSTARD PLANTS AS HOST FOR BEET LEAFHOPPER AND BEET CURLY TOP VIRUS

G.S. Banuelos, S. Tebbets, R. Perry, J.E. Duffus, and P.V. Vail

OBJECTIVES: To survey wild mustard as a habitat for beet leafhopper and determine whether it is a host plant for curly top virus.

PROCEDURES: Field experiments were conducted in west-central California between May and September on three different 0.1 ha field sites in two-week intervals. Two-week *Brassica juncea* seedlings were transplanted to each growing site on beds spaced 15 cm apart. Eighteen days after transplanting, the plants were sampled for leafhoppers at 10 A.M. using an insect-sweep net. Each sample consisted of eight random sweeps progressing from the outside towards the middle of the plot. Collected insects were placed into a glass jar and frozen for later identification. A total of four samples, twelve days apart, were collected at each field site.

Both *B. juncea* and *B. alba* (a mustard native to California) were inoculated with different strains of beet curly top virus (BCTV) (Logan, St-11, Fresno I and HRCT) and then monitored for BCTV by serological methods, enzyme-linked immunosorbent assay (ELISA). In addition to normal inoculation procedures (ten leafhoppers/plant with a three to four-day inoculation feeding period), a large number of viruliferous leafhoppers were colonized on test plants for ten days; adults were removed while developing nymphs were monitored for BCTV.

RESULTS: During the study we collected insects representing ten orders and over twenty-two families (data not shown). Only a small number of *Circulifer tenelus* was taken from all three mustard plots. A few specimens of two other leafhopper species were also collected: *Macrosteles quadraline atus Forbes*, the aster leafhopper, and an unidentified species in the *genus Empoasca*.

In the inoculation experiments, BCTV was not detected in beet leafhoppers after an acquisition period of three-four days on BCTV-inoculated mustard plants and also was not detected in developing nymphs after an acquisition period of ten days (Table 1). In addition, test plants assayed for the BCTV virus by ELISA were negative (Table 1). Similar tests with *B. alba*, a known susceptible mustard host produced positive results.

FUTURE PLANS: A manuscript has been submitted.

TABLE 1. Detection with ELISA and Virus Recovery in *Brassica juncea* and *Brassica alba* Infected with Different BCTV Strains.

Species	BCTV Strain	No. Plants	No. Beet Leafhoppers Per Plant	ELISA[a]	Virus Recovery[b]
B. juncea	Logan	20	10	-	-
B. juncea	St-11	20	10	-	-
B. juncea	Fresno I	20	10	-	-
B. juncea	HRCT	20	10	-	-
B. juncea	Fresno I	1	100 (colony)	-	-
B. alba	Fresno I	20	10	+	+
B. alba	St-11	20	10	+	+
B. alba	Logan	20	10	+	+

[a] Leafhopper giving ELISA values >0, three times healthy control: yes(+), no(-).
[b] Infection in plant tissue: yes(+), no(-).

EFFECTS OF SALINITY ON THE GERMINATION OF WILD MUSTARD

G. Banuelos, S. Zambrzuski, and S. Akohoue

OBJECTIVE: To determine the salinity tolerance of wild mustard at germination.

PROCEDURES: Greenhouse pot experiments were conducted in a temperate controlled greenhouse with a 16 h day of 850 $\mu mol_2\ m^{-2}S^{-1}$ irradiance and 21/18° C (day/night) temperature. The germination response of wild mustard was evaluated using single-factor with four salinity treatments and five replications. The treatments contained a basal level of 0.5 mM $CaCl_2$ and added salts at 0, 50, 100, 200, and 300 $mmol_c l^{-1}$. The salt mixture consisted of 5% Ca, 20% Mg, and 75% Na, and 50% C and 50% SO_4. Germination responses to the same salinity levels as above were also conducted after the surface of the soil had been sprinkled with fresh water (with an Ec less than 0.8 dSm^{-1}) after initial salt application. Twenty seeds were placed in 4 l pots containing 1 kg Panoche *Typic Torrithents* soil. When the emerged seedlings were approximately 2.5 cm high, salinity treatments were initiated. To avoid excessive plant damage due to osmotic shock, 20% of the total salts for each treatment were added every 2 d so that it took 8 d to reach the desired salinity level. Forty-five days after completion of the salt additions, all plants were harvested by clipping 20 cm above the soil surface. Plant shoots were dried, ground, and analyzed for Ca, Na by atomic absorption and Cl by potential metric titration with silver nitrate.

RESULTS: The germination responses of wild mustard to salinity are depicted in Table 1. Generally higher salinity levels retarded and reduced germination rate. Increased salinity levels resulted in higher levels of Ca, Na, and Cl than those plants growing in sprinkled saline soils. (Table 1). Sprinkling soil surface with non-saline water increased germination rate and led to a slight decrease in the accumulation of the tested ions.

FUTURE PLANS: A study is presently being conducted to study the effects of increasing salinity on the uptake of Se by wild mustard. A manuscript is in preparation.

Table 1 Germination responses and selected ion concentrations of wild mustard grown at increasing salinity levels and after sprinkling with non-saline water.*

Treatment (Ec,ds M^{-1})	Germination% of Control (%)	Dry Matter Yield (g $plant^{-1}$)	Ion Content Ca ($mg\ kg^{-1}$ DM)	Na	Cl ($mmol\ L^{-1}$)
Non-sprinkled					
<1	100	3.0	13980	5650	13.56
5	95	2.9	14560	25430	25.50
10	81	2.6	15840	34050	50.24
15	61	2.0	16530	39760	57.02
20	38	1.6	20470	56500	67.78
Sprinkled					
<1	100	3.3	12700	4990	12.50
5	97	3.0	15350	21780	22.65
10	89	2.7	16460	31000	45.03
15	73	2.2	17090	34503	51.05
20	47	1.6	20690	49700	62.70

* Values presented are means from two separate experiments, five replications per treatment, respectively. Means within a column followed by different letters are significantly different at the P=0.05 level by Duncan's Multiple Range Test.

WILD MUSTARD PRODUCES A PHYTOCHELATIN-Cd COMPLEX IN RESPONSE TO HEAVY METAL EXPOSURE

D.M. Speiser, S.L. Abrahamson, G.S. Banuelos,
and D.W. Ow

OBJECTIVES: To determine if phytochelatins (PC) are produced in wild mustard after exposure to cadmium or selenium.

PROCEDURES: *Brassica juncea, Lycopersicon esculentum* seedlings and *Schizosaccharomyces pombe* strain were grown in a conviron growth chamber and exposed to $CdCl_2$ or Na_2SeO_3 subsequent to the third set of true leaves and 30 h of growth, respectively. Plants and cells were removed from growth media (agar containing sucrose, vitamins, p-chlorophenolic acid and kinetin), washed, and then frozen in N_2. The tissue was ground, extracted with Tris pH 8.0, and the extracts were centrifuged. The extracts were then combined with glycerol, DTT, and brought to 1 ml with Tris pH 7.8, ^{109}Cd was then added to sample and incubated on ice. Extracts were applied to a DEAE-Sephadex column, which was washed twice with buffer solution. Phytochelatin (PC) containing fractions, determined by ^{109}Cd as a tracer, were combined and concentrated by vacuum centrifugation. $PC^{109}Cd$ profiles were determined by liquid scintillation counting using Beckman Ready Micro cocktail after extracts were subjected to gel filtration chromatography.

RESULTS: Phytochelatins are enzymatically synthesized peptides produced in plants and some fungi upon exposure to heavy metals. Phytochelatins form complexes with heavy metal ions and protect the plant from heavy metal toxicity.. *B. juncea* is known to have a relatively high rate of sulfur assimilation, which is believed partly responsible for this species high Se uptake. To determine if this vigorous sulfur uptake was reflected in high levels of PC synthesis and possibly incorporation of acid-labile sulfide ion into complexes with PC's and Cd, an extract from *B. juncea* was compared to *S. pombe*, as the organism in which synthesis of PC's has been most thoroughly studied (Fig. 1 & 2). *B. juncea* produced two Cd-containing complexes, corresponding to the two peaks in Figure 1. The PC composition in the other tested species were too low to report (data not shown).

Because the wild mustard is tolerant of high levels of Se, we were interested in inducing a PC synthesis in response to Se. After inducing seedlings with selenate or selenite, a clear signal was obtained from the Se-induced plants, although less than that from the Cd-induced seedlings (electrophoresis data not shown). The same was true of the extracts from Se- and Cd- induced *S. pombe*. The ability of wild mustard to produce a PC-Cd complex may contribute to its heavy metal tolerance. The PC-CD complex may be useful as a screening method for different plant species utilized for Se removal.

FUTURE PLANS: A manuscript has already been accepted.

Table 1. Sulfide and Cadmium Composition of HMW PC from *S. pombe* and *B. juncea*.

Organism	*S. pombe*	*B. juncea*
Sulfide (nmol)	33.5	8.2
Cd (nmol)	16.4	7.9
S^{-2}/Cd	2.0	1.0

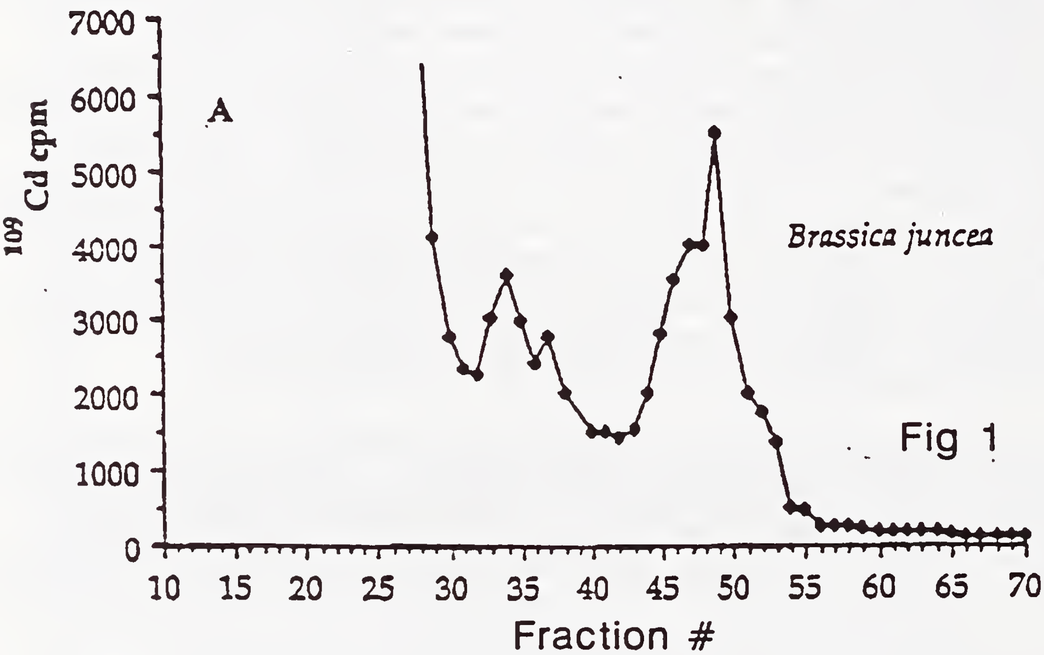


Fig 1

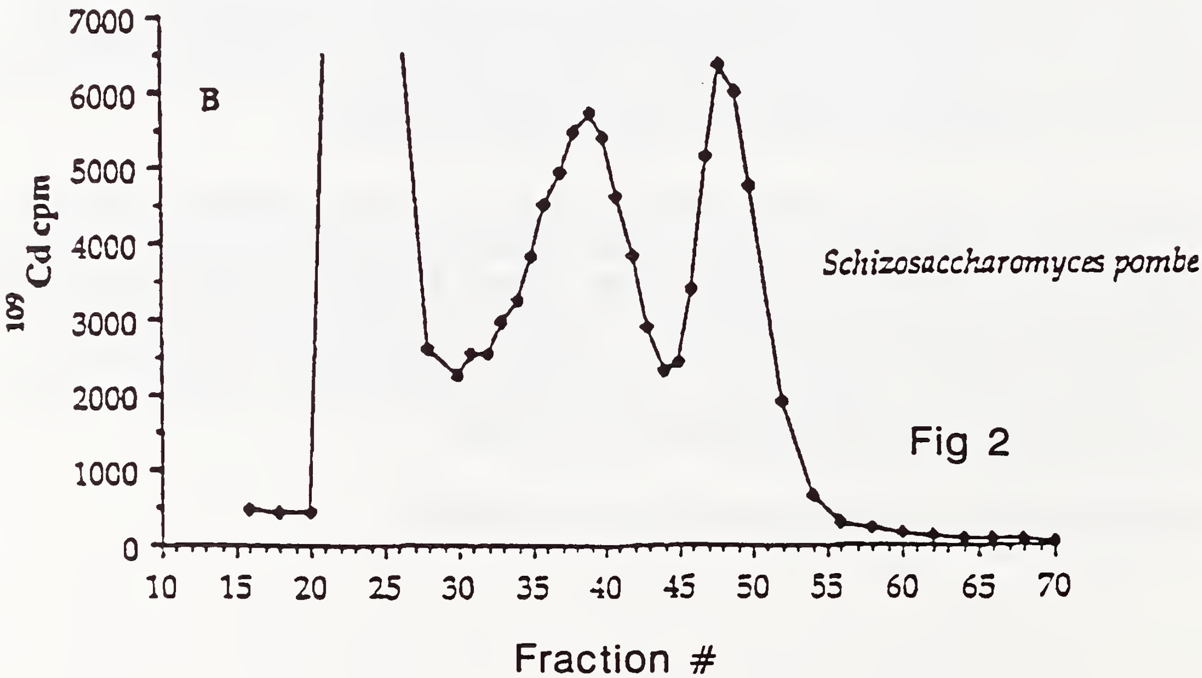


Fig 2

COMPARISON OF SELENIUM ACCUMULATION AND TOTAL PROTEIN IN DIFFERENT ACCESSIONS OF *BRASSICA JUNCEA*

G. Banuelos, S. Akohoue, R. Mead, and S. Zambrzuski

OBJECTIVE: Evaluate different accession of *Brassica juncea* for their ability to take up selenium.

PROCEDURES: Selenium uptake by selected accessions of *Brassica juncea* was investigated in water culture and in potted soil under greenhouse conditions during spring and summer of 1991. The plants were grown in a temperature controlled greenhouse with a 16 h day of 800 μmol $m^{-2}S^{-1}$ irradiance and a 21/18° C day/night temperature. In the water culture, four seedlings were transplanted into 4 l pots containing a 0.1 strength complete Hoaglands nutrient solution No. 2. After 7 d, the nutrient solution was replaced with a fresh Hoagland nutrient solution enriched with 2 mg Se L^{-1}, added as Na_2SeO_4. The Se-enriched solution was replaced every 7 d and water was added daily to maintain original volume. In the potted soil, seedlings were grown in 4 l growing pots which contained 1 kg of sterilized soil that had passed through a 1.2 mm mesh. After ten days, containers were reduced to four plants. For both water culture and potted soils Se was added as Na_2SeO_4 to give a total concentration of 2 mg Se L^{-1} or Kg^{-1} soil. Any leachate was reapplied in the irrigation water the next day. The experimental design for both cultures was a randomized complete block with five replicates per treatment. Plants were harvested 60 d after Se addition and separated into shoots and roots. For Se analysis the plant samples were dried for 7 d at 40° C in a forced draft oven, ground in a stainless steel Wiley mill, digested with nitric acid/hydrogen peroxide and analyzed for Se by atomic absorption spectrophotometry with continuous Se hydride generation. For protein analysis, tested samples were taken from plants grown (as described above) in either soil containing 2 mg Se kg^{-1} soil or no Se kg^{-1} soil, were immersed into liquid nitrogen, placed into freezer until analysis, and total crude protein determined by the Bradford method.

RESULTS: The data in Table 1 shows the differences in Se accumulation among the *B. juncea* accessions in both water culture and potted soil. Differences in Se contents are not as pronounced in the water culture as they are in the soil culture. Preliminary total protein data shows levels to be less in plants grown with Se compared to plants grown without Se (Table 1). Protein analysis are still in progress.

FUTURE PLANS: Protein analyses will be concluded. The best Se accumulators will be screened for salt, boron, and heat tolerance, and then planted to remove Se from Se-laden soils. A manuscript is in preparation.

Table 1. Accumulation of selenium and protein content in *Brassica juncea* accessions grown in both a Se-enriched or a non-Se enriched medium.*

Brassica juncea Accessions	Shoot Dry Weight (g/plant)	Root Dry Weight (g/plant)	Root Density (cm kg^{-1} soil)	Se Concentration From Plants Grown In Hydroponics (Se Kg^{-1} DW)	Se Concentration From Plants Grown In Soil (Se Kg^{-1} DW)	Protein *** +Se ($mg\ g^{-1}$ FW)	Protein *** -Se ($mg\ g^{-1}$ FW)
0	2.4	0.5	21	1100(150)	757(55)	144	125
1	2.4	0.6	24	932(56)	532(61)	82	141
10	3.1	0.4	25	850(71)	381(35)		
14	3.2	0.8	24	760(42)	421(17)		
15	3.4	0.9	15	750(63)	950(92)		
16	2.8	0.6	19	758(51)	968(83)		
17	2.2	0.5	19	970(85)	1100(105)		
18	3.4	0.7	18	1100(135)	421(52)		
19	2.7	0.6	18	980(44)	600(19)		
20	2.9	0.6	16	1350(180)	550(35)		

* Values presented are means of five replications followed by standard error of mean.

** Mean separation in columns obtained by Tukey's range test. The same letters represent no significant difference between species at the P=0.05 level.

*** Protein analysis is currently being conducted for the same species grown with selenium or without selenium.

COMPARISON OF DRY ASHING AND WET ACID DIGESTION ON THE DETERMINATION OF BORON IN PLANT TISSUE

G.S. Banuelos, G. Cardon, T. Pflaum and S. Akohoue

OBJECTIVES: To evaluate the effect of dry ashing and wet acid digestion on the determination of boron in selected plant tissues.

PROCEDURES: For boron (B) quantitative analyses, using the azomethine-H method, a Milton Roy Sepectonic 710 Spectrophotometer is used to determine the absorbance of B in solution at 420 mm. The calibration standards were checked throughout the analyses and were required to be within 5% of the known values (if 5% was exceeded, the standards were rerun). In both digestion techniques, samples consisted of 20-mesh dried ground Brassica juncea (wild mustard) plant tissue (contained high level of B) and NBS wheat flour reference material (contained low level of B). Plant tissue samples were analyzed in replicates of eight and repeated four times for each digestion technique for both mustard and wheat flour tissue samples.

a) Dry ashing consisted of placing 0.5 g dried plant tissue into a coal muffle furnace. Furnace controls were adjusted to reach 500° (in 2 hr. After an additional 2 hr. of heating at 500° C, ten drops of deionized water were added and ten drops of either a) sulfuric acid, b) nitric acid, c) 30% H_2O_2, or d) H_2O_2 + NaO^4. The crucibles were placed on a hot plate at 80° (and then reheated to 500° (for either 6 or 24 hr. oxidation period):

b) Wet acid digestion consisted of placing 0.5 g into 75 ml volumetric borosilicate glass digestion tubes, to which 5 ml 16 M HNO_3 were added. After 15 minutes, 1.5 ml of 18 M H_2SO_4 were added. The temperate of the heating block was initially set at 110° (for 1 hr. and then increased slowly to 180° (for either a 12 or 24 hr. oxidation period. Five ml 6 M HCl were added to each tube and filled to q volume with deionized water.

RESULTS: Higher levels of plant B were recovered from plant tissue prepared by wet acid digestion rather than with dry ashing (Fig. 1). Lower B concentrations were observed in samples heated for 24 hr. as opposed to 12 hr. by wet acid digestion (Fig. 1). No significant differences in recovered B were observed between samples dry ashed for 6 or 12 hr. (Fig. 1). Samples preheated with H_2O_2 produced the highest recovery among all dry ashing techniques, while samples treated with sulfuric acid resulted in the lowest B concentrations (Fig. 2).

FUTURE PLANS: A manuscript has already been accepted.

Figure 1: Mean B concentrations in wild mustard after dry ashing and wet acid digestion with varied lengths of oxidation periods.

Treatment 1 = Wild mustard dry ashed for 24 hr.; Treatment 2 = Wild mustard dry ashed for 6 hr.; Treatment 3 = Wild mustard wet acid digested for 12 hr.; Treatment 4 = Wild mustard wet acid digested for 24 hr.

A.O.V. F-test result = 538.81 (significant at P<0.01 level. Error bars indicate the 95% confidence intervals of their respective means using Tukey's range test.

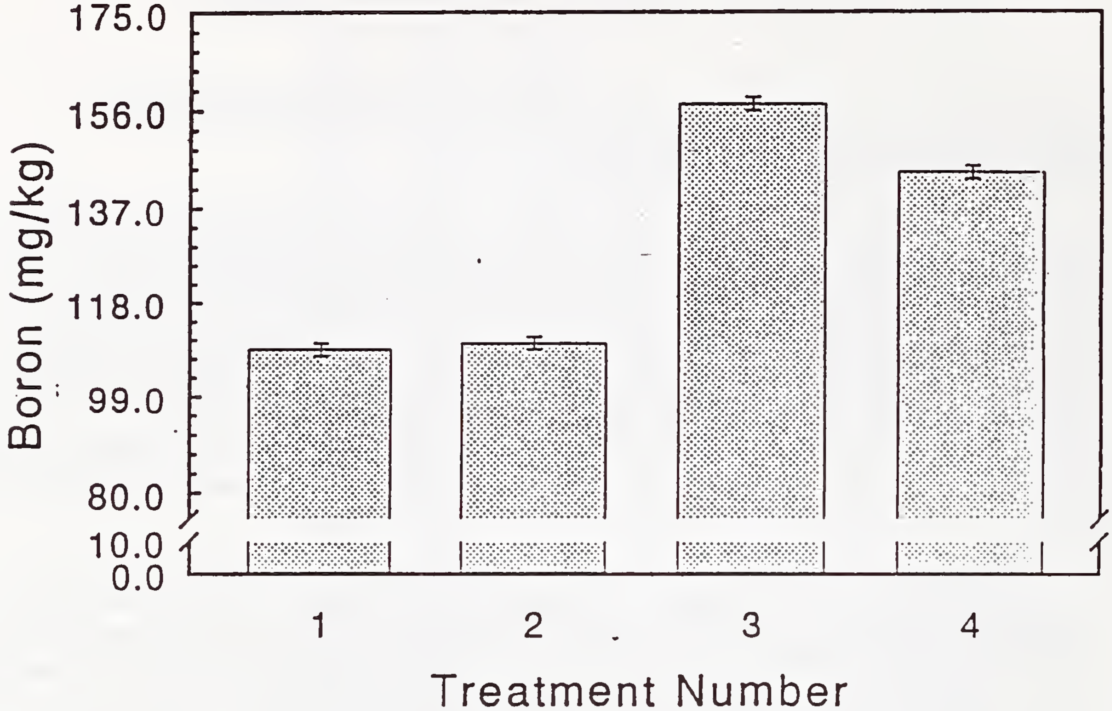
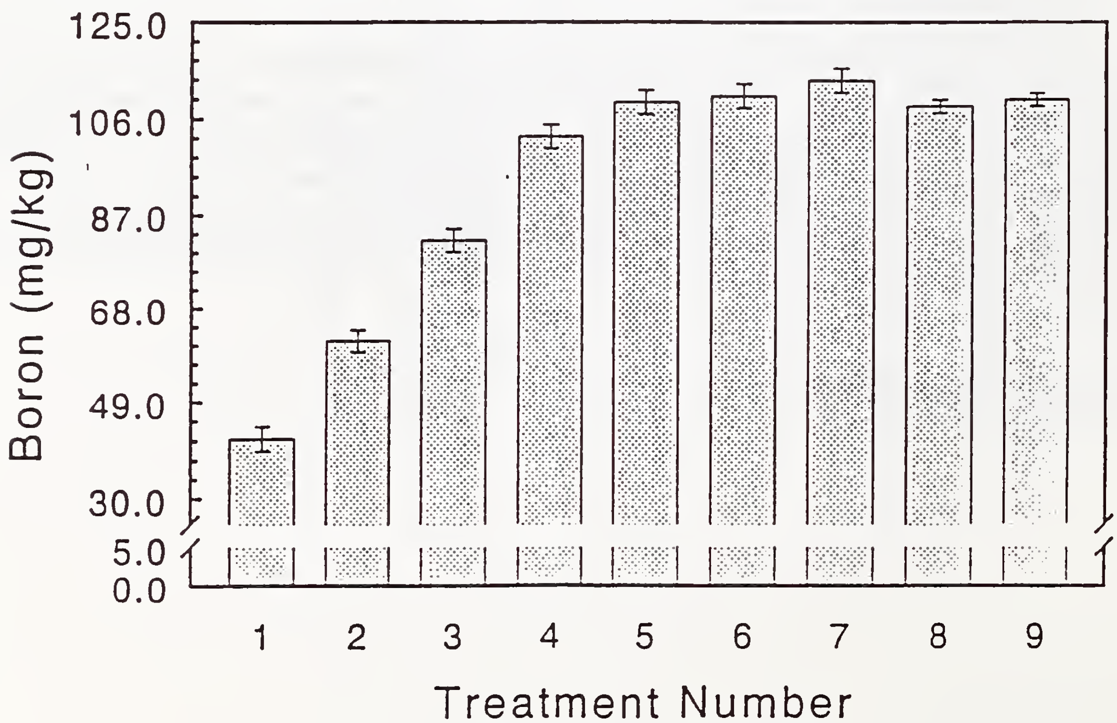


Figure 2: Mean B concentrations in wild mustard after dry ashing with varied ashing aids and lengths of oxidation periods.

Treatment 1 = Wild mustard pre-treated with sulfuric acid and dry ashed for 6 hr.; Treatment 2 = Wild mustard pre-treated with sulfuric acid and dry ashed for 24 hr.; Treatment 3 = Wild mustard pre-treated with nitric acid and dry ashed for 6 hr.; Treatment 4 = Wild mustard pre-treated with nitric acid and dry ashed for 24 hr.; Treatment 5 = Wild mustard pre-treated with hydrogen peroxide and dry ashed for 6 hr.; Treatment 6 = Wild mustard pre-treated with hydrogen peroxide and dry ashed for 24 hr.; Treatment 7 - Wild mustard pre-treated with hydrogen peroxide and sodium hydroxide and dry ashed for 24 hr.; Treatment 8 = Wild mustard pre-treated with no reagent and dry ashed for 24 hr.; Treatment 9 = Wild mustard pre-treated with no reagent and dry ashed for 6 hr.

A.O>V. F-test result = 538.81 (significant at P<0.01 level). Error bars indicate the 95% confidence intervals of their respective means using Tukey's range test.



ON THE SEPARATION OF ROOT TISSUE FROM SOIL SAMPLES

G.E. Cardon and J. Ben-Asher

OBJECTIVES: To develop a fast, simple method for determining the surface area and length of root tissue in soil samples taken for root distribution analysis of mature almond trees.

INTRODUCTION: Root tissue separation from soil samples is a difficult and time-consuming task, but one that is important in observing the rooting characteristics of plants. The use of such equipment as microwave ovens for sample drying and electronic video scanners for length and surface area measurements, can help speed the process. Correlating the results of simplified separations performed on small samples in batch-type procedures to those from more detailed methods, may also lead to reduction in the time required to process samples.

PROCEDURES: Field soil samples were mixed thoroughly to evenly distribute root tissue throughout the samples. Four subsamples of approximately 50 g were then removed from each field sample. The remainder of the field sample was saved for further analysis.

Each subsample was weighed and then dried in a microwave oven (Model R-9210A, Sharp Electronic Corp., Paramus, NJ) at low power (300 w) until the sample weight loss stabilized (approximately 10 min.). After cooling, each subsample was reweighed for gravimetric water content determination.

After drying, the samples were placed in a large mortar and lightly crushed to disintegrate any large aggregates. The crumbled samples were then placed in 500 ml beakers to which deionized water was added (approximately 400 ml).

After the samples were sufficiently wetted, each was agitated to separate the organic matter (which floated) from the soil. The samples were allowed to settle for four hours and the supernatant was decanted and filtered to capture the organic matter (primarily consisting of root tissue). Following decanting the deionized water wash was repeated.

Filtered samples were dried in a microwave oven at low power until the sample weight loss stabilized. Each filter paper with its captured organic matter was weighed on an analytical balance (Mettler HL52, Mettler Instrument Corp., Hightstown, NJ) for later determination of dry matter weight.

Filtered tissue samples were then analyzed for total length and surface area by the intersect method using video root scanning equipment (Decagon Delta-T, Model ITC-510, Pullman, WA). The root separation method just described will be referred to hereafter as the partial method.

The remainder of each field soil sample was then processed by the method used by Phene, et al. (1991). This method of root separation from soil samples is commonly used and serves as a comparison to the proposed method. For convenience, the method used by Phene et al. (1991) will be referred to hereafter as the full method. This method involves hand separation of root tissue from other organic matter. The waste organic fraction collected from the full method samples, was also analyzed for length and surface-area. This was done to quantify the error introduced into the measurements taken on the partial method samples by not separating root tissue from other organic matter.

RESULTS: A summary of the time required by the same lab assistant to process samples by both separation methods is presented in Table 1. The full method requires more time. The full method also must be performed on each individual sample, where, with the partial method, the size of the samples allows groups of several samples to be included in the most time-consuming step of microwave drying. The full method also requires the difficult and often time-consuming hand separation of root tissue from waste organic matter.

Graphical comparisons of total root length and surface areas between the two methods are given as Figures 1 and 2, respectively.

Table 1. Comparison of the time required to separate root tissue from a simple soil sample using the full and partial methods.

Partial (time per sample)	Minutes	Full (time per sample)	Minutes
Microwave sample drying	20	Separation washing	20
Deionized water washing/filtering (not including settling time)	15	Hand removal of waste organic matter (including drying of samples)	30
Sample weighing	1	Sample weighing	1
Video measurements	1	Video measurements (larger samples were broken into smaller units for measurements)	3 to 5
Total	37		54 to 56

The two figures show that measurements using the partial method are slightly higher compared to the full method where waste organic matter (trash) is removed. However, when trash is included, the two methods are very similar. In all cases there is high linear correlation between the two methods which provide accurate conversion between the measurements (Table 2).

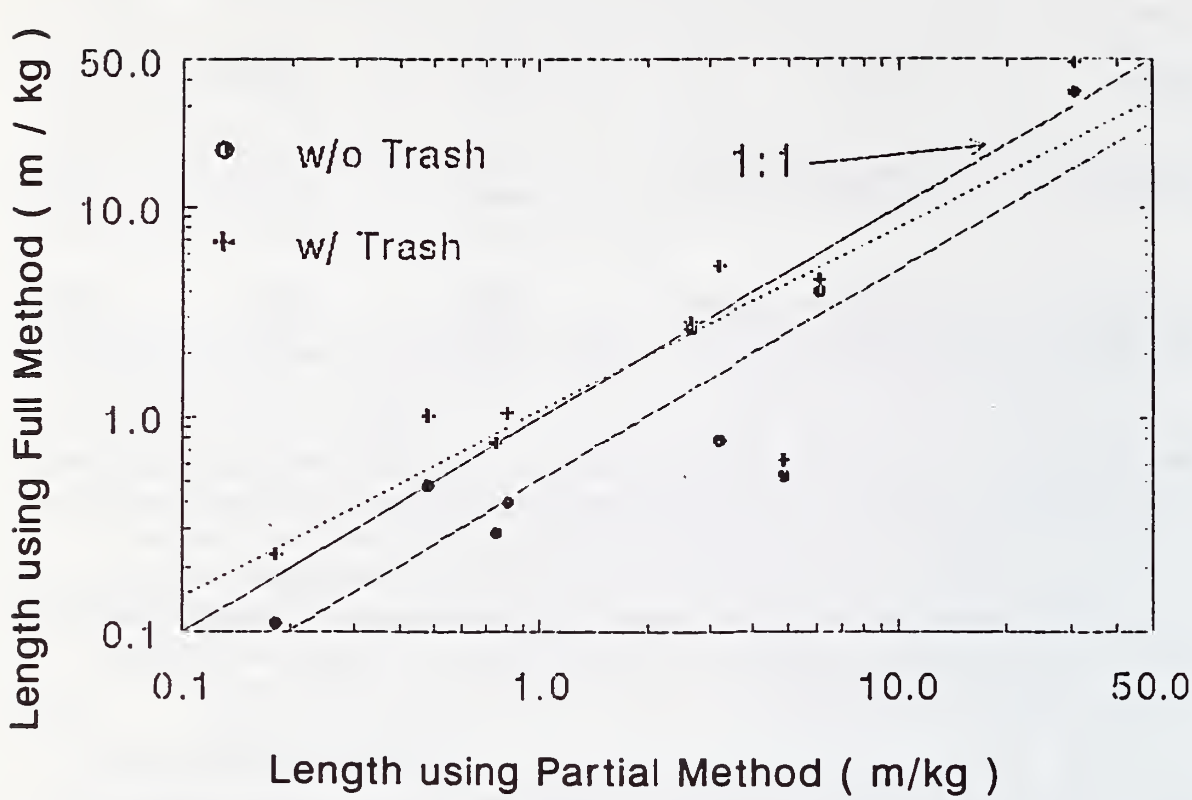
Table 2. Regression coefficients and statistics for data presented in Figures 1 and 2.

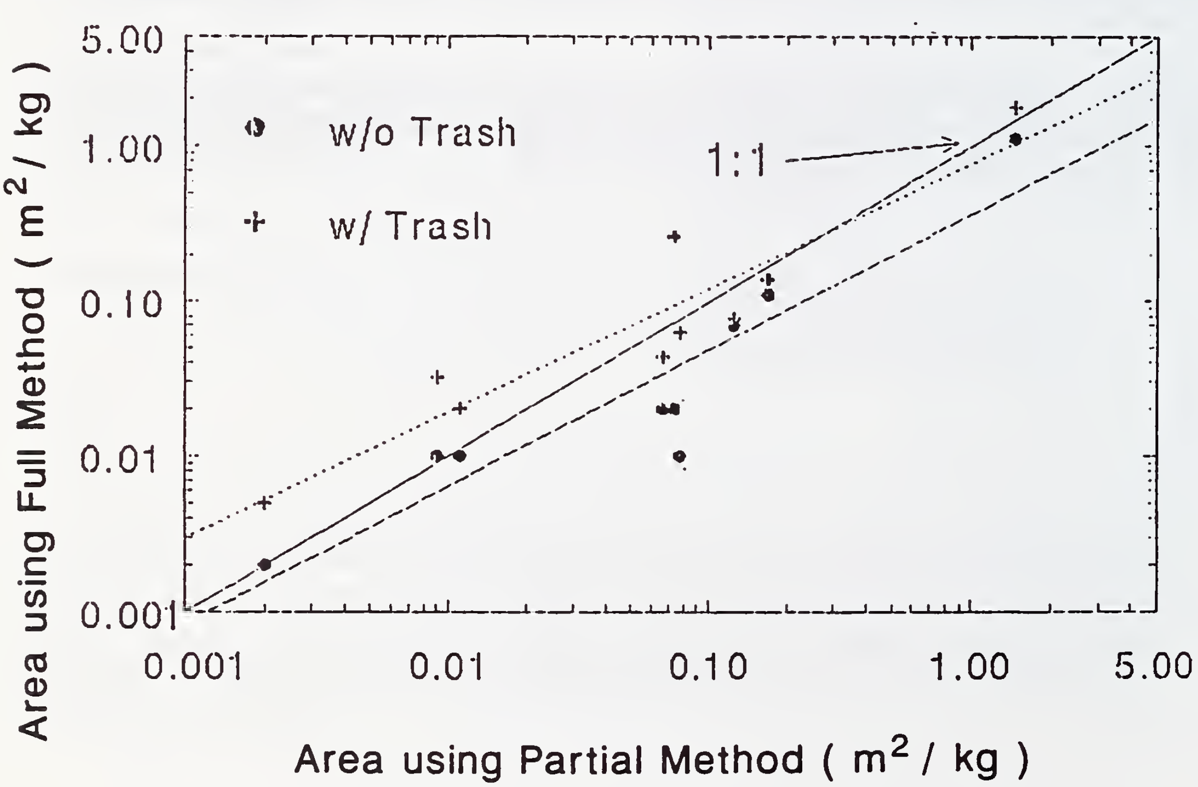
X-Variable	Y-Variable	Slope	Intercept	r
Length				
Partial Method	Full Method w/o Trash	0.996	-0.29	0.90
Partial Method	Full Method w/ Trash	0.870	0.04	0.86
Area				
Partial Method	Full Method w/o Trash	0.879	-0.44	0.93
Partial Method	Full Method w/ Trash	0.804	-0.111	0.93

CONCLUSIONS: The proposed root separation method is simple, fast, and not as subjective as previous methods since it does not require hand separation of root tissue from other waste organic matter. The comparison of the proposed method to the currently used method showed it to provide similar measurements of sample root length and surface-area. Moreover, the high correlation between the methods allows one to take advantage of the time saving aspects of the proposed method and accurately estimate root length and/or surface area from the resultant tissue samples.

FUTURE PLANS: Further replication of the comparisons will be made and a manuscript prepared for eventual submission as a technical note or short communication to a peer-reviewed journal.

REFERENCES: Phene, C.J., K.R. Davis, R.B. Hutmacher, B. Bar-Yosef, D.W. Meek and J. Misaki. 1991. Effect of high frequency surface and subsurface drip irrigation on root distribution of sweet corn. Irrigation Science 12:135-140.


50.0
10.0
1.0
0.1
w/o Trash
w/ Trash
1:1
0.1
1.0
10.0
50.0
Length using Full Method (m / kg)
Length using Partial Method (m/kg)


5.00
1.00
0.10
0.01
0.001
w/o Trash
w/ Trash
1:1
0.001
0.01
0.10
1.00
5.00
Area using Full Method (m2 / kg)
Area using Partial Method (m2 / kg)

SUPPORT LABORATORIES

ANALYTICAL CHEMISTRY LABORATORY

T.J. Pflaum, W.M. Pranger-Chin, G.S. Banuelos,
and B.H. Hagans

The main purpose of the Analytical Chemistry Laboratory is to support field research projects for the Water Management Research Laboratory. The types of samples analyzed include soils, water, and plant tissue. The total number of analyses performed for 1991 was 25,500. The total number of all samples was 3100.

During the year, 18,100 analyses for cations and anions were performed on a total of 1900 soil samples. In addition to the soil samples, 600 water and 600 plant tissue samples were examined for a total of 5700 and 1700 analyses, respectively.

During the past year, there have been significant changes in the laboratory personnel. Dr. Harry I. Nightingale, Soil Chemist, retired and Dr. Gary S. Banuelos, Plant Nutritionist, was given the responsibility of overseeing the operation of the Chemistry Laboratory. All but one of the 1990 laboratory personnel have left, however new people have been hired. To give some permanence to the laboratory, Winnett Pranger-Chin, was hired as a full time federal employee in the chemistry laboratory.

There have been important changes in the laboratory equipment as well. The long awaited Inductively Coupled Plasma Spectrophotometer (ICP) was purchased. The laboratory was physically modified to accept the ICP and many of the analyses done by the Atomic Absorption Spectrophotometer and UV-Visible Spectrophotometer will now be done faster and more accurately on the ICP. The UV-Visible Spectrophotometer will now be used only occasionally. The Alpkem Rapid Flow Analyzer Nitrate Cartridge has been validated for the analysis of nitrate/nitrite in plant tissue, soil extracts, and water samples.

ELECTRONICS ENGINEERING LABORATORY

D. Clark, T. Lockner, M. Norman

The Electronics Engineering Laboratory provides electronic, computer, and related services in support of research projects. The year's work was dominated by the installation of new automated data acquisition and irrigation control systems. The new projects were located at the Irrigated Desert Research Station in Brawley, California; at Britz Farm near Mendota, California; and at the West Side Field Station on the 54 plots field.

The Brawley project was a major installation requiring power, water, telephone, and data/control lines to be put in. An existing lysimeter was converted to an automated irrigation control system. Another system was installed to control the irrigation and measure the pressure and flow of eight treatments divided between two crops using two paralleled pumps. The above two systems were connected to a telephone modem through a code operated switchbox for remote access from Fresno. An on-site weather station was upgraded and setup to use an automated evaporation pan.

An evaporation pan system was installed at Britz to control the irrigation and measure the pressure and flow of ten treatments divided between two crops. Signal conditioning circuits were built for the flow sensors. The system was connected to a modem that was interfaced to a cellular transceiver for remote access.

A system was installed at the West Side Field Station to control the irrigation of eighteen treatments. The system was linked to the grass lysimeter for irrigation scheduling and connected to the existing modem/switchbox for remote access. The CIMIS weather station was converted from a CR21 to a 21XL datalogger.

Datalogger programs were written and daily reports set up for all of the above systems. The automatic data system was transferred to a faster computer with a larger hard drive. The data system was improved with software upgrades. Other work included computer and electronic repairs, routine maintenance, and miscellaneous data processing.

The work load for the year was heavy. Stable student workers and help from others outside the Electronics Laboratory contributed significantly to productivity. With plans for additional automated systems, however, more help may be required to maintain the existing systems and minimize problems.

PUBLICATIONS

Papers Published in 1991

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